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A JOB FOR HISTORY ENTHUSIASTS

FOR a number of weeks now there has been discussion both orally and in print regarding certain first flights made in this country, but not necessarily by Englishmen. Part of this discussion has been taking place in the pages of THE AEROPLANE. A convenient starting point may be taken with the decision reached by the superintendent of the Royal Aircraft Establishment, Farnborough, to re-word the plaque on the withered tree on the edge of the airfield, commemorating the first flight by S. F. Cody at Farnborough in 1908. This decision was come to after independent inquiries had been set in motion at the R.A.E. and by Mr. Charles Gibbs-Smith who besides being a keeper at the Victoria and Albert Museum also specializes in aeronautical history. These inquiries satisfied the inaugurators of the inquiries that the date of Cody's first flight, hitherto accepted by both the R.A.E. and Mr. Gibbs-Smith, was in fact erroneous and that another date in 1908 should be adopted, or homologated, as the appropriate day. This decision is not accepted by Mr. G. A. Broomfield, Cody's biographer.

We rather sympathize with Mr. George Fyffe writing in the *Daily Telegraph* who said that the actual day did not seem important; surely it was the year that mattered.

In the course of the debate an important aspect has been raised and discussed. Captain Laurence Pritchard, Hon. F.R.Ae.S. and for so many years the secretary of the Royal Aeronautical Society, comments in this issue on the remarkable selection by Dr. Gardner of the R.A.E. and Mr. Gibbs-Smith of the mystical figure of 1,320 ft. as the appropriate criterion for a sustained flight. Now this seems to be in conflict with the decision of the well-known Gorell Committee which sat in 1928. Their definition of a power flight was:

> "Free flight of an aeroplane occurs when, the machine having left the ground, it is maintained in the air by its own power on a level or upward path, for a distance beyond and over which gravity and air resistance would sustain it."

Professor E. J. Richards, of Southampton University, has since stated that a flight of 100-150 ft. at a speed of 30 m.p.h. or so and never at a height greater than 3 ft. would satisfy this definition.

Strenuous efforts to get power-driven aircraft into the air became increasingly practised as the nineteenth century ended and the twentieth began. In those early days every hop was an encouragement to efforts to prolong such hops farther. Progress was measured by lying down and looking to find daylight beneath the bumping wheels as the primitive aircraft tumbled over the ground. Sir Hiran Maxim's flying machine, it will be remembered, broke the rails intended to hold it down—an early example of a tethered aircraft getting out of control! Selection of an arbitrary figure of 1,320 ft. in such circumstances seems likely to upset some accepted firsts.

Discussion of this subject cannot proceed very far without encountering the persistent efforts made by the young Alliott Verdon-Roe to get his own-built biplane into the air at Brooklands in the year 1908. These efforts are commemorated by the plaque unveiled by "A.V." himself in 1954. His son, Mr. Geoffrey Roe, has now collected enough supporting evidence from contemporary sources to ask that the findings of the Gorell Committee be reviewed, for this committee decided that the famous pioneer did not fly that year.

Anyone who goes searching for contemporary records of aeronautical achievement in this country soon finds that such material is hard to come by and, furthermore, that the aeronautical community in this country is extremely haphazard in preserving its records. Not many people are interested in keeping crumbling news-cuttings and yellowing photographs, though more are interested in early aeroplanes and aero engines. In this latter field the Royal Aeronautical Society, as the oldest body of its kind in the World, has learnt to acknowledge its responsibilities. It acquired much merit by taking over the Nash collection. The Shuttleworth collection is managed by a private trust. But the enthusiasts are not satisfied and claim that there are a further three or four dozen ancient aircraft in this country which should be preserved from the scrap heap.

A proposal is being canvassed to form an Air Historical Society to canalize enthusiasm and co-ordinate the collating of information and records. Such a body might, in the opinion of some, salvage certain elderly aircraft, now crated at an Air Ministry storage depot, of which a select few are re-erected annually for the Battle of Britain ceremonies while the rest, it has been alleged, are in danger of incineration at fire-fighting displays.

If such a body can be brought into being, surely the most useful inaugural task it could perform would be to dig out, and set forth, the record of the pioneers of flight in this country: who they were; what they did and when they did it. And we should be surprised if in that list the name did not rank high of that pioneer Englishman, who built his own aeroplanes, taught himself to fly them and founded the name which has meant so much in British aviation: AVRO.

MATTERS OF MOMENT

Aero-Engine News

FROM the S.B.A.C. comes more encouraging news about the cash value of British aero-engines now being exported. During the first four months of this year the average weekly income from overseas orders in this category was no less than £900,000. This is certainly a remarkable increase over the corresponding figures for previous years—£376,000 in 1955, £511,000 in 1956, and £688,000 in 1957. Indeed, as the S.B.A.C. points out, the day when British aero-engines will be earning a million pounds sterling in the export markets every week cannot be far away.

During the four months under review (from January to April) the total aero-engine export value was no less than £15.5 million. This represents an annual earning rate of £46.5 million which compares very favourably indeed with the record figure of £40.6 million attained in 1957. If this new annual total eventually materializes for 1958, it will be more than double the annual totals of 1953-55 inclusive and will represent a five-fold increase of the 1951 and 1952 totals.

Other British aero-engine news last week came from Bristol Aero-Engines, Ltd., who announced that their Olympus 201—or B.Ol.7—had successfully completed an official type test at a thrust rating of 17,000 lb. Previously, the highest official Olympus thrust was 16,000 lb.—for the B.Ol.6 These two engines are externally similar but differ in some internal respects that have not been revealed to date on the grounds of security. Bristols claim that as a result of its recent achievement, the B.Ol.7 has the highest thrust/weight ratio of any current high-thrust engine that has been type tested.

Bristol Aero-Engines have also announced that they have received another order from Japan for Orpheus turbojets. These will be used to power further examples of the Japanese Fuji basic jet trainer.

R.O.C. Jubilee

SOME 300 members of No. 5 (Watford) Group of the Royal Observer Corps attended a dinner in the Queen's Building restaurant at London Airport on June 7, to celebrate the Silver Jubilee of the Group's formation in 1933. No more appropriate place could have been chosen, because the Airport is within No. 5 Group's area of responsibility, while its present Commandant, Obs. Cdr. G. A. D. Bourne, is both R.O.C. Liaison Officer at the Airport and Manager of the Airport Branch of Barclays Bank.

After dinner, the toast to the Royal Observer Corps was proposed by the Airport Commandant, Mr. G. J. H. Jeffs, who said that he was an old friend of the Corps, having been a controller at Fighter Command H.Q. before and during the Battle of Britain in 1940. He added that he was always pleased to welcome officially organized parties of observers at the Airport and to let them see the radar rooms and other places not normally open to the public—all of which should be good for the present recruiting campaign!

Other guests included Obs. Capt. W. Rusby, Deputy Commandant of the Corps, Obs. Capt. B. Parks, Commandant Metropolitan Area, and the Commandants of Nos. 1, 2 and 4 Groups. B.O.A.C. added a touch of glamour by loaning Stewardess French to draw the winning numbers in a raffle for some very worthwhile prizes given by friends of 5 Group.

R.O.C. GUEST.—Mr. G. J. H. Jeffs, M.V.O., O.B.E., Commandant of London Airport, delivers his speech as the guest of honour at the 25th anniversary dinner of the No. 5 (Watford) Group R.O.C. On his left are Observer Commander G. A. D. Bourne and Obs. Capt. W. Rusby.

MILES DEMONSTRATION.—The Service potentialities of the Miles H.D.M. 106 Caravan project were shown recently by a demonstration with the H.D.M. 105 experimental "test-bed" aircraft of similar type. A number of typical standard military loads—such as the one here being put aboard—were dropped by parachute; the craft was flown without its rear door.

Trade-in Techniques

THERE is growing concern among aircraft manufacturers in this country at the readiness of U.S. manufacturers to buy back obsolete or obsolescent aircraft, provided their own products are bought as replacements. It is worth noting that *Time*, the U.S. newsmagazine, for June 2, reports:—

"U.S. aircraft manufacturers are adopting an old-fashioned marketing technique: the trade-in allowance. Boeing has agreed to take back 14 propeller-driven Stratocruisers when it delivers its 707s to British Overseas Airways Corp., and has offered to give trade-in allowances on nine more 707s to Northwest Airlines. Douglas is negotiating with United Air Lines to take in some

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DC-7s as a down payment on 30 DC-8s; Lockheed is dickering in the same way to sell its turboprop Electras. . . ."

The *Time* item continues: "No jetmaker is happy about getting into the secondhand plane business because that market is already poor. As recently as 18 months ago, demand was so strong that fully depreciated planes could often be sold for more than they cost; ancient DC-3s were bringing $140,000 v. an original cost of $85,000. But with turboprops and jets on the way, airlines lost interest in slower aircraft, and prices tumbled 40% to 60%.

"American Airlines, which has four DC-7s currently for sale and may have up to 25 more by July, 1959, is asking $1,200,000 for an aircraft that cost $2,000,000 new. A DC-6B that cost $1,300,000 might have a trade-in value of $750,000, but would fetch far less in the open market."

Among ideas being discussed to deal with this problem is the formation of a concern, to be financed by the manufacturers, to handle the business of selling the "trade-ins." In this country manufacturers are hard put to finance the construction of commercial aircraft. Financing of sales is a second headache but we have heard of no plans that would make possible the buying back of obsolescent products to achieve sales of British aircraft.

As a footnote it should be recorded that a DC-3 is still worth £45,000.

Westminster Flies

ON June 15 the flying test-rig prototype of the Westland Westminster helicopter made its first flight at Yeovil. At the controls was Lt. W. H. Sear, Westland's chief test pilot; with him was Mr. L. Devigne as co-pilot and Mr. G. Smallridge as flight test observer. The Westminster was airborne for 1 hr. 4 min. Its first flight followed a series of ground trials which were completed ahead of schedule in only 12 days.

Construction of the prototype Westminster began only eight months ago. It has been developed as a private venture by Westlands and is the largest private-venture helicopter to be built by a British manufacturer. Messrs. D. Napier and Son, Ltd., have shared in this private enterprise by developing the rear-drive Eland gas-turbine engines which power the Westminster.

All-up weight of the Westminster is 33,000 lb. Its 5-bladed main rotor has a diameter of 72 ft. and the fuselage is 70 ft. long. In its utility form it can be used as an aerial crane which carries a load of up to 15,000 lb. suspended from a strong-point built into the fuselage. In the transport version, it will seat up to 45 passengers. The Westminster has an estimated cruising speed of 150 m.p.h. and a range with allowances of 320 miles.

Rapid development of the Westminster prototype has been possible because it uses many components of the Sikorsky S.56 helicopter. The five-bladed rotor, its hub and shaft, the tail-rotor assembly and duplicated power controls are actual S.56 parts which are backed by 70,000 hours of flying experience with the S.56. Thus the new features of the Westminster are confined to its powerplant, transmission and airframe. The reasons which led Westlands to choose the Eland engine for the Westminster were summarized in THE AEROPLANE last week.

Two prototypes of the Westminster are to be built with tubular-frame fuselages. The first, which has just flown, will act as a flying test-rig to investigate engine transmission and control problems; the second will have a somewhat lighter fuselage and will in effect be the prototype of the flying-crane Westminster. Tests with these prototypes will provide information for the design of the transport Westminster's light-alloy stressed-skin fuselage.

More Manned Aircraft for the U.S.A.F.

PROCUREMENT plans for the U.S. Air Force in 1959 have indicated that many more manned aircraft are to be ordered, in addition to a large number of missiles, and the development of piloted machines of extremely advanced design is to continue. Nearly 1,000 aircraft will be purchased for a total cost of about $45 billion, and the development is being accelerated of Mach-3 bombers and fighters for later procurement.

North American Aviation, Inc., is working on both the latter projects, which each employ the General Electric J93 turbojet. The bomber design, which began life as Weapons System 110A and has now been designated the B-70 by the U.S.A.F., uses six J93s with chemical or "zip" fuel, which are intended to provide normal operating speeds of M=3 at altitudes of more than 60,000 ft. Not unnaturally, this project has officially been described as probably more difficult to develop than ballistic missiles, but it is hoped to reduce the planned development time by about 18 months. The Mach-3 interceptor-fighter is a long-range design using two J93s, which has been designated the N.A. F-108, and appears to be a rather longer-term project.

Immediate bomber procurement involves the purchase of 47 Convair B-58 Hustlers, which are capable only of M=1.7, or about 1,150 m.p.h., and with four J79-GE-1s, weigh a mere 160,000 lb. each. Hustlers are equipped for flight refuelling, which will greatly extend their supersonic range. An additional 26 Boeing KC-135s are being purchased in 1959 as flight-refuelling tankers to augment the power of the bomber force, which will also be expanded by the procurement of about 39

MIGHTY WEIGHT-LIFTER.—Maiden flight of the Westland Westminster helicopter took place at Yeovil on June 15. Aboard the Westminster were (l. to r.) Lt. W. H. "Slim" Sear, Westland's chief test pilot, Leo Devigne, co-pilot, and Gerry Smallridge, flight test observer.

Boeing B-52G Stratofortress heavy bombers. S.A.C. plans to replace its B-47s by B-58s, and B-52s are re-equipping B-36 Wings. The Stratofortress will ultimately be replaced by the North American B-70.

Fighters ordered for 1959 include McDonnell F-101 Voodoos; Republic F-105D and F-105E single- and two-seat fighter-bombers for Tactical Air Command; and Convair F-106A Delta Darts, armed with Hughes Falcon explosive AAMs and Douglas MB-1 Genie atomic guided weapons. In the transport field, more of the massive Douglas C-133 turboprop aircraft will be ordered, to bring the eventual total to about 100.

R.A.F.A. and Publicity

WITH something like ninety-thousand members, the Royal Air Forces Association is a vigorous well-organized body. It is based on a multitude of locally based branches organized into regions. Once a year the executives and branch delegates meet at the annual conference. This makes for a social occasion as well as providing a forum for necessary business.

It was interesting for a guest to the recent Conference in Edinburgh to find how many resolutions were connected with public relations. One of them was so critical of the executive effort in this field that it was not surprising that Dame Katherine Trefusis Forbes rose to make a spirited reply which effectively squashed the resolution and merited the applause unstintingly given. Dame Trefusis Forbes had been at pains to remind the Conference of the success of certain film premieres with the attendant publicity and welcome addition to the funds of R.A.F.A.

Next day we were early on the scene in Princes Street, Edinburgh, for the gathering of the delegates with the scores of branch banners of Air Force blue. Headed by a pipe band the procession made its way down Princes Street and into the sunlit gardens beneath the castle wall. The sight that Sunday morning was certainly as fine a spectacle as we have seen, yet the citizens of Edinburgh were not present in force, indeed it would be fair to say they were not present at all.

It may well be that there was no intention that they should be. But as we walked away after the service of remembrance we wondered whether it might be that it is at branch level that the Royal Air Forces Association is not sufficiently well known. We wondered whether ex-members of the R.A.F., wherever they may be, are sufficiently aware of the work that is waiting for them to do in the local branch of the R.A.F.A.

Air Sport at Coventry

A PARTICULARLY varied programme has been arranged for this year's National Air Race meeting at Coventry, between July 10 and 12, when in addition to the usual racing and aerobatic events, a parachute jumping competition has been organized between members of the British Parachute Club.

In the air display, there will be the usual R.A.F. and U.S.A.F. participation, including the aerobatic team of No. 111 Squadron, and of C.F.S. Jet Provosts. But the Army will also take a hand with demonstration parachute jumps.

The large entry for the Lockheed aerobatic competition includes last year's winner, V. Krysta, from Czechoslovakia, with five of his compatriots (Z. Beseda, J. Blaha, J. Hulka, K. Krenc and M. Prikryl), in Zlin Treners or single-seat Akrobats. Former winner, L. Biancotto is also flying a Zlin 226 this year, and there are four other French entrants, flying Stampe SV4 biplanes. Six British pilots are to fly the special Tiger Moth G-APDZ, and Capt. D. W. Phillips is to fly the rebuilt Arrow Active, G-ABVE.

Other biplanes taking part will be a Bü 131 Jungmann, from Germany, flown by Capt. J. Ederer, and a Bü 133 Jungmeister from Switzerland, piloted by F. Liardon.

Full list of entrants, with pilots, aircraft and registration is:—

The Kemsley Challenge Trophy: J. E. G. Appleyard, Chilton D.W.1a, G-AFSV; H. B. Iles, Miles M.18 II, G-AHKY; Wg. Cdr. R. H. McIntosh, D.F.C., A.F.C., Percival Proctor III, G-AECJ; A. J. Spiller, Percival Proctor III, G-AHFK; A. S. K. Paine, Percival Proctor I, G-AHNA; T. K. Knox, Percival Proctor III, G-AIHD; A. Barker, Percival Proctor III, G-ALFX; P. Blamire, Miles Gemini 1a, G-ALZG; E. Crabtree, Miles Gemini, G-AKEG; G. Marler, Miles Falcon Six, G-ADTD; F. Dunkerley, Miles Gemini M.65 I, G-AKKB; R. R. Paine, Miles Hawk Speed Six, G-ADGP; F. Dunkerley, P. S. Clifford, Percival Mew Gull, G-AEXF; (provisional) F. Dunkerley, Miles Sparrowjet, G-ADNL.

The Osram Cup: S. S. Miles, B. Maile, Aeronca Champion, G-AOEH; Northern School of Aviation Flying Club, D. Westoby, Auster Autocrat, G-AIPV; G. F. Hancock, Turbulent, G-APKZ, K. B. Neely, Auster V, G-AKTF; C. E. Elton, Arrow Active, G-ABVE; N. H. Jones, D.H. Hornet Moth G-AEWY; C. A. Nepean Bishop, D.H. Tiger Moth, G-APDZ; Sqn. Ldr. J. E. Doran-Webb, J. Heaton, Thruxton Jackaroo; A. J. Linnell, D. F. Ogilvy, Comper Swift, G-ABUS; N. H. Jones, D. Hartas, Thruxton Jackaroo, G-ANZT; W. H. Bailey, Miles Hawk Trainer III; W. P. Bowles, Miles Monarch, G-AIDE; J. Hill, Tipsy Belfair, G-AFJR.

The Goodyear Challenge Trophy (for Tiger Moths): W. V. Fitzmaurice, G-AOAA; F. T. Francis, G-AOXJ; J. H. Denyer, G-AIVW; J. Pothecary, G-APJP; J. M. Donald, G-ANZU; Captain D. W. Phillips, G-ACDC; N. H. Jones, Miss M. MacKellar, G-ANZZ; B. J. Snook, G-ANSH; A. G. Oldham, G-AODR; C. Boddington, G-AOXS; J. A. Wardley, G-AHNI; W. P. Meynell, G-ANEL; P. Statt, H. A. G. Smith, G-AOXN; M. H. Reid, G-AOZB.

World Gliding Championships

Leszno, Poland.

JUST four days were taken by the British team for the World Gliding Championships to drive from London to Leszno, passing across the territory of seven countries and through six pairs of customs posts.

After driving the five cars and four trailers into the grounds of Buckingham Palace to receive the good wishes of the Duke of Edinburgh, with tea, and then rigging and de-rigging the Skylark 3 on the Horse Guards' Parade, the party set out for Dover at 18.00 hr. on June 6. They crossed to Dunkirk next morning, and later, on entering Holland, were surprised to find an official escort of motorcycles.

A few miles into Germany, and we were at the N.A.T.O. camp outside Mönchen Gladbach, where the British Army gave us a comfortable night and saw us safely on to the autobahn next morning, bound for Nürnburg. Our party:

Cdr. Nicholas Goodhart, R.N., with his own Skylark 3, and Lorne Welch and Brian Jefferson as crew; Lt.-Col. Anthony Deane-Drummond, with Eon Olympia 419, and his wife and John Archer as crew; Philip Wills, with a Skylark 2 to fly in the "Standard" 15-metre class, with his wife and Ray Stafford-Allen as crew; and Lieut. Cdr. Antony Goodhart, R.N., with the Eon Olympia 415, also for the Standard class, and Frank Irving and Peter Swift.

There is also a "base team" consisting of C. E. Wallington as meteorological adviser, John Williamson as radio expert, Harry Midwood, who played a large part in converting the Olympia to laminar flow, and Ken Owen to look after publicity.

The fifth car was in charge of Ann Welch, the team manager, and carried three passengers officially classified as delegates to the OSTIV Congress at Leszno—Betsy Woodward, Alan Yates and myself. We had intended to spend our fourth day travelling 400 miles from Nürnberg in Germany to Leszno in Poland, having only transit visas for Czechoslovakia; but by then it was obvious that our drivers were too tired and we would have to spend a night in Czechoslovakia after all and somehow raise the money to do so on a Sunday. This we were able to do at a place called Hradac Kralove, through the good offices of the British Air Attaché in Prague.

Our team manager's car reached Leszno at 15.00 hr. on June 9, followed at intervals by the others, and we found we were fifteenth to arrive out of 22 national teams expected. Of the countries represented in France at the last Championships, Switzerland, Spain, Brazil and Turkey are not competing this year, but two newcomers to World Championships are Russia and Rhodesia (strictly, the Union of Socialist Soviet Republics and the Central African Federation). Other parts of the Commonwealth entered are Canada, South Africa, Australia and New Zealand.

The Russians are all flying Polish machines—three Jaskolkas in the Open Class, and a Mucha-100 in the Standard Class; I understand that their own sailplanes take an inordinate time to rig and derig, but they hope to remedy this situation by the next championships.

There are 62 entries altogether—38 in the Open and 24 in the Standard Class. There is nothing really new in the entries for the first of these classes, except for an occasional modification of a previous type, such as our own Olympia 419.

There are two quite different competitions for the Standard Class. One is to see which can win most points in championship flying; but the other is for an OSTIV prize for the machine which best serves the purpose for which this class was instituted—i.e., to produce something cheap and simple to build and easy to handle both in the air and on the ground. The new French Breguet 905, for instance, is beautifully made, with every aerodynamic refinement possible, and wings which are said to weigh only 75 lb. each; it may well win the first of these prizes, but is unlikely to win the second.

Practice flying began on June 10 for the British team, some of whom had to iron out a snag or two in their instrumental equipment; then on June 11, in unpromising weather, a task was given: 70 km. to Sroda, upwind to the N.E., and back. Nicholas Goodhart was among the few who got there, or nearly there, and part of the way back. The tugs are of Junak (monoplane) type, with towing cables of only 65-ft. length, which our pilots find rather strange.—A. E. SLATER.

The Starfighter's Double Crown

AS the current holder, pending homologation, of both the absolute speed and altitude records of the World, which never before have been secured by the same aircraft, the Lockheed F-104A Starfighter is all the more remarkable in being a standard military design in full squadron service. When the first Starfighters became operational at Hamilton AFB in January, 1958, the Lockheed company requested permission from the Pentagon to attempt a number of records, including speed, altitude, rate of climb and cross-country performance, but it was not until May that clearance was obtained. The new records of 1,404 m.p.h. and 91,249 ft. were then set up within two weeks.

Details of how these record flights were achieved have now become available, and reveal some extremely significant features of F-104 performance. In both records, speeds of more than M=2 were commonplace, and for the altitude performance, the F-104 was climbing at a constant M=2.1 at 40,000 ft., at a rate of 20,000 ft./min., before zooming up at no less than 80,000 ft./min.

Before attacking the height record, Lockheed had to present a case to the F.A.I., through the U.S. National Aeronautical Association, to change the method of altitude recording from the time-honoured sealed barograph technique to ground instrument observation. This has become necessary with the zoom technique because the aircraft is at its peak altitude for so short a time after a rapid climb that conventional altimeters under-read by several thousand feet through instrument lag. As a result of these representations, new measuring techniques were approved at the F.A.I. meeting in Los Angeles in the spring, and a triangular photo-theodolite system was employed soon afterwards for the U.S. Navy height record of 76,828 ft. with a special Grumman F11F-1F Tiger.

This performance brought the aircraft altitude record briefly back to the U.S. after an absence of 28 years, until beaten a few weeks later by the Sud-Aviation Trident. The F-104A, which was already preparing to win back the record, had the benefit of 20% more power at altitude with its later version of the Tiger's afterburning J79-GE-3 turbojet, and in production test flights, Lockheed pilots were frequently reaching 75-80,000 ft. measured by radar from Edwards AFB.

Before Lockheed attacked the height record, engineering test pilots Jake Holliman and Bill Park began exploring the zoom technique, starting at 55,000 ft., with an initial speed of about M=2, but found that the F-104A was reaching only 80-82,000 ft. It was felt that the Starfighter could do a good deal better than that, and the problem was submitted to an electronic calculator. Surprisingly enough, the answer given was to go lower before starting the zoom, to get maximum acceleration at about 45,000 ft., and give more time to reach the optimum climb angle with an excess of speed.

On the first flight with this technique, more than 87,000 ft. was reached, and Park then achieved 90,900 ft. Three pilots, Maj. H. C. Johnson, Capt. W. W. Irwin and Capt. J. Low, from the 83rd Fighter-Interceptor Squadron, the first U.S.A.F. Starfighter unit, were then assigned to Lockheed's for both the speed and altitude attempt, starting with the latter, for which Maj. Johnson, as senior pilot, was selected. Although an experienced pilot, with 1,800 of his 4,600 flying hours in jets, Maj. Johnson had less than 50 hours on F-104s, but he made six practice flights, all in excess of the American 77,000 ft. record.

As the French were then reaching 80,000 ft., it was necessary to go considerably higher to ensure a comfortable record. Each flight involved zooming up on virtually a ballistic trajectory, necessitating extremely precise flying. From about 65,000 ft. and above, when the afterburner of the J79 flamed out through lack of oxygen, virtually no thrust could be counted on to assist the climb, but even at the peak altitudes, engine combustion of a sort was apparently maintained. Slightly more than normal windmilling r.p.m. was indicated, together with a low J.P.T. reading.

The record height was achieved early in the morning of May 7, after take-off at 09.39 hr., and climbing with intermittent afterburner near the Pacific Coast to reach the optimum fuel load before the zoom run. This was started near Mt. Pinos, with "full uniform" afterburning, accelerating to M=1.7 at 35,000 ft., and then to 2.1 I.M.N. while ascending to 40,000 ft., by 09.58 hr. Maintaining M=2.1, Maj. Johnson continued at about 20,000 ft./min. until 45,000 ft. was reached, when he zoomed up at a 35 degree angle, pulling 2½ *g*, and climbing at about 80,000 ft./min. to 65,000 ft.

MANNED MISSILE.—The Lockheed F-104A Starfighter holds (subject to confirmation) simultaneously the absolute speed and altitude records of 1,404 m.p.h. and 91,249 ft. It is armed with a single multi-barrel 20 mm. T171 Vulcan cannon.

It seems that this was the point of afterburner flame-out, and Maj. Johnson then had to maintain a climbing attitude at just under 1 *g* to avoid a stall. He also had to contend with the inflation of his MC-1 partial-pressure suit, as the cabin pressure dropped to the equivalent of about 45-50,000 ft., necessitating a high degree of constriction on the pilot. At the top of the climb, at a true height of 91,249 ft., when the nose began to drop gently despite continued slight aft pressure on the stick, the F-104A was just subsonic, indicating 80-100 knots, for a T.A.S. of about 623 m.p.h. The demand on extreme flying skill continued during the descent, in which full r.p.m. and normal J.P.T.s were apparently reached again in the region of 70,000 ft. Total flight time was only 27 minutes.

For the speed record, Capt. Walter Irwin was given a deadline of May 17—Armed Forces Day—which left less than a week for the job to be done. The earlier XF-104, with the low-powered J65, had flown at M=1.79, or 1,150 m.p.h. as long ago as March 25, 1955, and on April 27, 1955, the late J. Ozier exceeded M=2 (1,320 m.p.h.) in the F-104A, but with the big J79 the main problem was not so much speed as keeping within the 100-m. height limit while entering the 4½-mile funnels and the 10.1-mile course.

About half a dozen practice runs were made at 40,000 ft. during the first two days, before the first record attempt at dawn on Thursday, May 15. Apart from the positioning problem, the main difficulty governing the maximum speed was the rise in compressor inlet temperature through kinetic heating. To avoid burning out the engine, it was actually necessary to reduce afterburner power during the record runs, but reheat was continued during the re-entry turns as it had been found that less fuel was then required than to throttle back and accelerate again.

The course-end turns were done at 3 *g*, while maintaining nearly M=2 at not more than 1,640 ft. above the 40,000 ft. course, the height of which was marked by two Lockheed T-33s carrying NAA observers. On the third flight of the speed record attempt, more than 1,500 m.p.h. was achieved, but a wire failed in the afterburner nozzle control mechanism, and high cloud then prevented subsequent runs. On Friday, an average of 1,435 m.p.h. failed to be recorded by the ground cameras, and the F-104A used, which had a later series engine with a higher permissible intake temperature, also became unserviceable, necessitating its replacement by an earlier series Starfighter.

A second flight was made the same morning, and despite all the difficulties, including a blown canopy on one of the two observation T-33s, Capt. Irwin managed two runs, at 1,465.41 and 1,342.97 m.p.h., vectored by radar, giving an average speed of 1,404.19 m.p.h., which was submitted as a record.

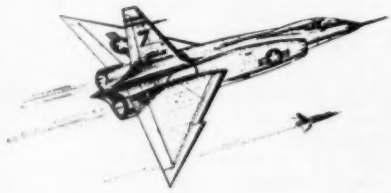
News of Aircraft, Engines and Missiles

THOR FIRING.—A Douglas Thor IRBM has been successfully fired from a mobile tactical launcher of the type to be used by operational units. All previous firings at Cape Canaveral have been made from an immobile research and development test stand.

EXETER DISPLAY.—More information has reached us about the air display to be held at Exeter Airport on June 28 at which aircraft of the R.A.F., the Royal Navy and the U.S.A.F. will be on show. These include Valiants, Vulcans, Canberras, Hunters, Javelins, Vampires, Sea Venoms and Gannets. The Tiger Club and the parachute section of the Plymouth Aero Club will also give demonstrations. The display is organized by the R.A.F.A. and Exeter Aero Club and will be opened by Sir Frank Whittle.

ZERO-LAUNCHED.—A fully-loaded F-100D Super Sabre has been zero-launched using a 130,000-lb. thrust Astrodyne solid-propellant rocket. North American Aviation say that this system will enable fully-loaded fighters to be kept in readiness near the front line.

1,000,000-LB. THRUST.—Dr. Herbert Yorke, chief scientist of U.S. Defence Department's advanced research projects, has stated that his department intends to begin work, within the next few weeks, on a space-vehicle engine developing a thrust of 1,000,000 lb. In Dr. Yorke's view the U.S. is only a little more than a year behind the Soviet Union in this sphere. Of more than 60 proposals for space-vehicle launching submitted to the department, only half a dozen have passed preliminary tests and are receiving study.



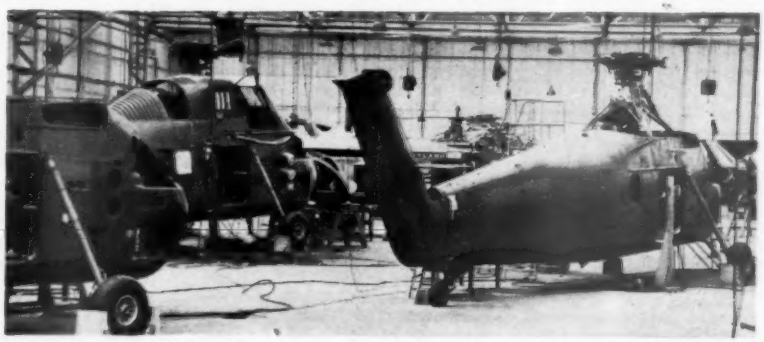
EVENTUAL VERTIJET.—This sketch, from *Ryan Reporter*, shows what may be the layout of the supersonic interceptor development of the Ryan X-13 Vertijet. It is remarkably similar to the Avro Arrow in layout.

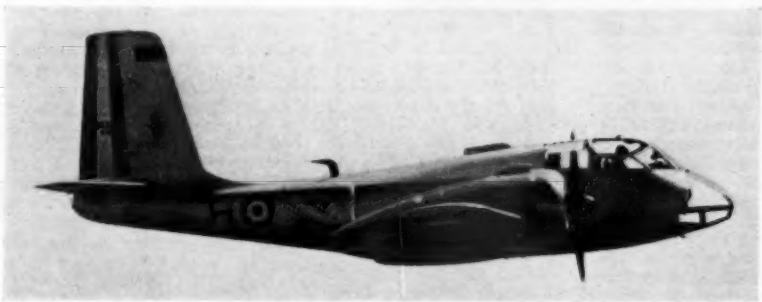
HARPOON EXECUTIVE.—The prototype executive conversion of a Lockheed PV-2 Harpoon has been produced by Oakland Automotive Co. and was recently rolled out. It has been named the Centaurus, and has already been sold. It seats 8-14 passengers and is powered by two Pratt & Whitney R2800 engines, giving a cruising speed of 280 m.p.h. The cabin is pressurized.

HYPERSONIC BOMBERS. — Bell Aircraft and Martin are reported to be involved jointly on the U.S. Dynasoar project for a boost-glide bomber. American sources state that the U.S. is behind Russia in this field and that the Soviet T4A manned rocket bomber is ready for flight testing.

TITAN SITE.—According to reports from America the first U.S. launching site for the Titan ICBM will be near Denver, Colorado.

HILLER UH-12-E.—Deliveries of the Hiller UH-12-E helicopter can be made in Britain as from November this year provided operators can arrange import licences. This helicopter cruises at 82 m.p.h., has a useful load of 1,000 lb. and a range of 185 miles. It has a 305 h.p. Lycoming engine and the overhaul life of all major components is 1,000 hr. Its cost in Britain will be just over £21,000.





WESSEX ASSEMBLY.—Above, a recent photograph of the assembly line of the pre-production Westland Wessex helicopter at Yeovil. The first pre-production Wessex off this line should have made its first flight by the time these words are read.

FLYING SOLDIER.—First flight of the Sud-Aviation SE.116 Voltigeur tactical support aircraft was on June 5. Production versions will have two 650 s.h.p. Turboméca Bastan turboprops; the prototype has 800 h.p. Wright Cyclones.

Commercial Aviation Affairs

312s FOR AFRICA.—As already announced, B.O.A.C. is to put Britannia 312s on the London-Johannesburg services on July 27. Training flights over the routes started on June 9.

CIRCULAR TOURS.—Because of the increased number of applications for circular tours, and the similarity of some of them to normal inclusive tour services operated under associate agreements with the Corporations, the Minister of Transport has asked the A.T.A.C. to include these among the services for which the Council gives him advice.

FERRY INCREASE.—According to provisional figures, Silver City carried 4,388 cars and 12,548 passengers during May—by comparison with 2,821 cars and 8,100 passengers during the same month

TWO FOR QANTAS. — These two D.H.C. Otters—one a landplane and the other an amphibian—were handed over to Qantas Empire Airways on May 27. Two more are due to be delivered shortly and all four will replace D.H.C. Beavers and a Catalina on New Guinea services.

NEW TASK.—A Bristol 170 of Air Charter, Ltd., which has been flying meat into this country during the dock strike.

last year. Car bookings for 1958 now exceed 41,000. In April, last year, nearly 10,000 cars crossed the Channel to France and one in seven went by air; in April, 1958, nearly 12,000 made the crossing and one in four went by air.

KUWAIT AGREEMENT.—B.O.A.C. has signed a five year agreement with Kuwait Airways by which the Corporation will be responsible for the management and operation of the services. Extensions of Kuwait's operations are planned—including Viscount services to London.

THE BOLTON ACCIDENT.—In conformity with our usual custom, the points made at the public inquiry on the accident to a Silver City Bristol 170 at Winter Hill, near Bolton, will be discussed when the report has been issued. The inquiry started on June 12 and a number of critical matters had already been raised during the first two days.

NEW ARCTIC SERVICE.—K.L.M. plan to start their Arctic route service from Amsterdam to Tokyo and Biak on November 1, using DC-7Cs. The service will be flown twice-weekly via Anchorage, Alaska, and (westwards) a so-far-unnamed refuelling point.

B.K.S. TO NORWAY.—As we briefly forecast in the issue of June 6, B.K.S. Air Transport inaugurated their twice-weekly Newcastle-Bergen (Flesland) service with Airspeed Elizabethans on June 4. B.K.S. now have three Elizabethans arranged as 55-seaters.

RECESSION.—The traffic at U.K. aerodromes during March showed something of the effect of the present recession in air transport. Although the number of aircraft movements rose by 8% to 19,213, the number of passengers, at 365,921, showed an increase of less than 1% on the figure for March, 1957. Freight, however, increased by 8% and there were very big passenger increases at Ferryfield (129%) and Rhoose, Cardiff (154%).

More News Items appear on page 876

Birthday Honours

A SUPPLEMENT to the *London Gazette* published on June 3, included the following civil list Birthday Honours conferred by Her Majesty the Queen. (Honours included in the military lists are on page 847.)

BARON

Sir (Thomas) Ellis Robins, K.B.E., D.S.O., E.D., lately chairman, Central African Airways. For public services in Rhodesia.

ORDER OF THE BATH

As Companion

M. B. Morgan, Deputy Director, Royal Aircraft Establishment, Farnborough.

ORDER OF SAINT MICHAEL AND SAINT GEORGE

As Knight Commander

Air Vice-Marshal Sir Robert A. George, K.C.V.O., K.B.E., C.B., M.C., R.A.F. (Retd.), Governor of the State of South Australia.

As Companion

Air Marshal D. Colyer, C.B., D.F.C., R.A.F. (Retd.), Civil Aviation Representative in Western Europe, M.T.C.A.

ORDER OF THE BRITISH EMPIRE

As Commanders

E. K. Cole, chairman and managing director, E. K. Cole, Ltd.; H. Harvey, O.B.E., Assistant Secretary, Air Ministry; E. S. Moult, Director and Chief Engineer, de Havilland Engine Co., Ltd.

As Officers

J. K. Garland, Senior Chief Executive Officer, Air Ministry; D. N. Harrison, Principal Scientific Officer, Meteorological Office, Air Ministry; H. C. Hawkins, Principal, Air Ministry; L. Haworth, chief designer, civil engines, Rolls-Royce, Ltd.; Wg. Cdr. F. F. James, for political services in Southampton; Wg. Cdr. R. C. Lawes, senior overseas liaison officer, International Aeradio, Ltd.; E. V. P. Miller, Senior Air Traffic Control Officer, Northern Division, M.T.C.A.; J. H. Morley, Engineer I, Royal Radar Establishment, M.o.S.; P. Rowbotham, Principal Inspector, Inspectorate of Armaments, M.o.S.; S. P. Simcocks, Deputy Chief Quantity Surveyor, Air Ministry; G. Thompson, Assistant Director (Programmes) Air, M.o.S.

As Members

A. B. Archer, Higher Executive Officer, Royal Observer Corps, Air Ministry; J. D. Browning, chairman of committee, Nos. 66, 97 and 1924 (Croydon) Squadrons, A.T.C.; G. M. Cox, M.C., A.F.C., lately Assistant Airport Manager, Preswick Airport, M.T.C.A.; H. Finch, Signals Officer, M.T.C.A.; R. Gray, chief designer, Chloride Batteries, Ltd.; Miss E. E. Grinsted, lately Executive Officer, R.A.E., Farnborough; R. W. Hanwell, Senior Executive Officer, No. 35 Maintenance Unit, R.A.F., Heywood; H. Heynes, Senior Executive Officer, Air Ministry; E. A. Humphry, Deputy Superintendent, Directorate-General of Works, Air Ministry; Brigadier M. A. James, V.C., D.S.O., M.C., D.L., civil defence officer, Bristol Aeroplane Co., Ltd.; C. E. Jowitt, Senior Experimental Officer, Meteorological Office, Aberporth, Air Ministry; E. G. Kirby, Senior Signals Officer, M.T.C.A.; W. Low, Executive Officer, M.T.C.A.; Captain J. H. H. Mills, D.F.M., Chief Pilot and Operations Superintendent, Aden Airways, Ltd.; A. G. Nunn, senior planning engineer, B.O.A.C.; R. H. C. Phillpott, lately Higher Executive Officer, Air Ministry; G. W. Pitt, director, Eagle Aviation, Ltd., and Eagle Airways, Ltd.; J. Riley, works manager, Burnley Aircraft Products, Ltd.; H. G. Roberts, Senior Technical Superintendent, No. 33 Maintenance Unit, R.A.F. Lyneham; C. P. V. Roche, lately Airport Commandant, States of Jersey Airport; S. J. O. Sarr, station manager, West African Airways Corporation; H. B. Stewart, chief photographer, B.E.A.; R. Thurley, Station Superintendent, Belfast, B.E.A.; G. T. White, works manager, Guided Weapons Division, Sir W. G. Armstrong Whitworth Aircraft, Ltd.; E. A. Williams, secretary of committee, No. 936 (Hertford) Squadron, A.T.C.

IMPERIAL SERVICE ORDER

As Companion

J. H. Keys, Chief Executive Officer, Air Ministry (Sonning-on-Thames).

QUEEN'S COMMENDATIONS FOR VALUABLE SERVICE IN THE AIR

Captain N. R. G. Barker, senior captain, second class, B.E.A.; Sq. Ldr. J. S. Booth, D.F.C. (deceased) lately chief test pilot Saunders-Roe, Ltd.; Captain R. F. Caspareuthus, staff pilot, Directorate of Civil Aviation, East Africa; Lieutenant-Commander N. N. Ducker, R.N. (Retd.); Captain D. W. Fenton, chief pilot and operations manager, Malayan Airways, Ltd.; Captain H. L. M. Glover, senior captain, first class, B.O.A.C.; G. L. Howitt, D.F.C., test pilot, Air Registration Board; Lieutenant-Commander H. G. Julian, D.S.C., R.N.; Captain J. Monro, senior captain, first class, B.O.A.C.; Captain A. C. J. Scadding, senior captain, first class, B.O.A.C.

HONOURED.—Left to right, Mr. M. B. Morgan, deputy director of R.A.E. (C.B.); Dr. E. S. Moult, director and chief engineer de Havilland Engine Co. (C.B.E.); Mr. L. Haworth, chief designer, civil engines, Rolls-Royce Ltd. (O.B.E.).

AIR TRANSPORT

No Millennium Yet

FOR a few minutes last week a series of handouts from the General Precision Equipment Corporation of New York got us all excited about the possibility that someone had finally solved the problems of air traffic control.

After mulling through the quite considerable amount of material it turned out that the G.P.E.C. was saying no more than that a self-contained airborne system of continuous position-fixing was the obvious answer to the A.T.C. problem and that their RADAN Doppler equipment provided just such an ideal system. With special instrumentation the General Precision Laboratory's RADAN equipment had, as it turned out, merely been given a new name, HIDAN—for high-density air navigation.

Now the G.P.L. has done immensely important work on Doppler systems (prototype equipment was produced 10 years ago) and has more recently, under contracts from the U.S. Air Modernization Board, been developing an experimental semi-automatic A.T.C. data-processing system—but they must not cry "Eureka" (or even "Rebecca") for no good reason.

Self-contained Doppler systems are fine—and will no doubt be a great help in solving the problems of accurate navigation for the benefit of air traffic control. But they cannot provide a simple, sole and final answer, because the errors of such systems, however small, are cumulative. Monitoring and position-checking aid from ground-based sources will, it seems, always be necessary—and air traffic controllers, if they are to do their job properly, will continue to demand confirmatory evidence of tracks and timed positions.

Regrettably, G.P.L.'s HIDAN offers no prospects for an A.T.C. millennium. We remain tranquil but expectant.—H.A.T.

Inter-airport Transport Problems

FOR heavily populated capital or metropolitan cities, such as London and New York, where multiple airports need to be used to cope with the air traffic, the problem of inter-airport transport has always been with us. To a large extent the difficulties have been eased for the New York area by the partial segregation of services according to route, by surface coach services and, more recently, by subsidized inter-airport passenger helicopter services.

But the problem still remains, even for New York, and an international passenger arriving at, say, Idlewild and flying through on a service which leaves from Newark, New Jersey, may find that something like three hours need to be allocated, on a bad-weather day, for the journey to the East Side Terminal, across Manhattan to the West Side Terminal, and out to Newark.

For London the problem had not been particularly acute before the re-opening of Gatwick. Nearly all the trunk services had used London Airport and even when Northolt was a civil airport the distance to and from L.A.P. was short enough to be an easy bus journey. Gatwick, however, alters the situation very much indeed. The surface journey between L.A.P. and Gatwick will, even in normal conditions, take from two to three hours and will involve three separate operations, including a cab-ride between the West London Air Terminal (or Airways Terminal) and Victoria Station.

Not unnaturally, this question (amongst others concerned with service and staff integration) is exercising the minds in British European Airways—who will obviously find it necessary, in due course, to operate more services out of Gatwick in addition to those to and from L.A.P.

Early this year B.E.A. received a seven-year approval from the A.T.A.C. and M.T.C.A. for the operation of internal services between L.A.P., Gatwick and Southend. A significant feature of this approval was that the Corporation has permission to operate either helicopter or fixed-wing services. At present no suitable helicopters exist, and no background of necessary experience has been built up for a really effective all-weather inter-airport helicopter service to be operated, so the obvious solution will be the use of fixed-wing aircraft.

But, as Lord Douglas points out in the current issue of the *B.E.A. Magazine*, it will be necessary to use special routeings, quite clear of the normal traffic patterns, between the airports if a successful "inner circle" service is to be operated with fixed-wing aircraft. Nevertheless, the project seems to be worth immediate study, since such operations will at least be reasonably economic as well as practical from the passengers' point of view, whereas a helicopter service would be very expensive and with existing weather limitations hardly regular enough for serious use by earnest inter-airport commuters.

Incidentally, the inter-airport service idea is not a new one. In pre-War days Air Dispatch, of Croydon, operated just such a series of flights—and called it the London Inner Circle Air Service.

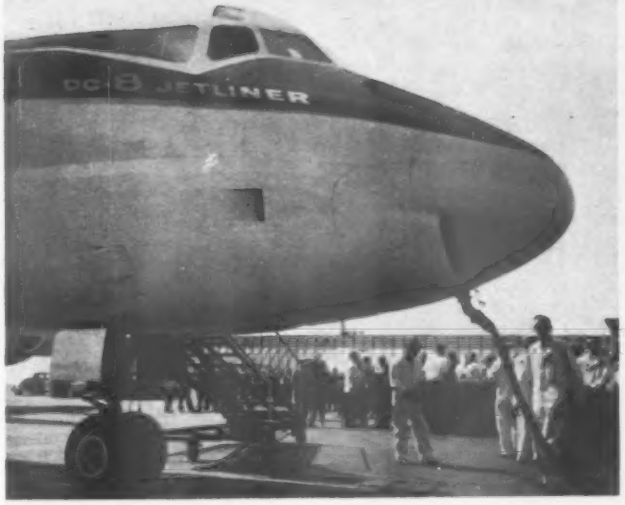
The Comet and New York

THE Port of New York Authority, properly careful of its rulings on aircraft noise at its four airports, has given qualified permission for the Comet 2E to use New York International Airport for proving and training flights by B.O.A.C. even though this variant has not had its noise level checked by the Authority's engineers.

Tests by de Havilland, however, have shown that the 2E's noise level is 2 db. below that of the tested Comet 4 prototype (Comet 3) at a point 2.2 miles from the start of take-off roll. At this distance the 2E is at an altitude of 1,300 ft., whereas the Comet 3 is at 900 ft.

Permission has been granted for daylight-only landings and take-offs in visual flight rule conditions while conforming to the "preferential runway" system.

FIRST PRODUCTION CARAVELLE.—Here at Sud-Aviation's Toulouse/Blagnac factory, the first production Caravelle (for Air France) is seen in the foreground, with the two prototypes (in S.A.S. and Air France markings) in the background. According to reports last week-end, S.A.S has taken up its option on six more of these aircraft—making 12 in all on order, with an option on 13.



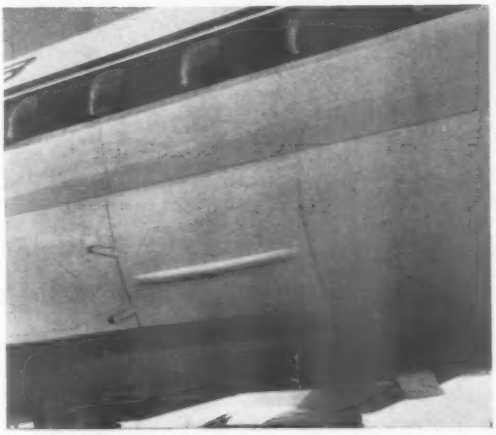
Above, the intake of one of the JT-3C engines, showing the lip for oil cooler air. The flush intake on the right is for generator cooling.

Left, the "nostrils" in the nose of the DC-8 form the air intakes for the cabin air-conditioning system.

DC-8 Details

Photographs copyright "The Aeroplane"

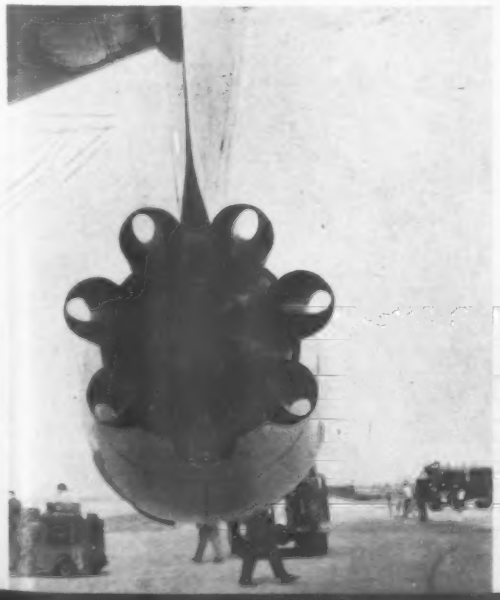
Above, the DC-8 gets airborne at Long Beach for the first time, on May 30, trailing prominent black streamers.



Above, speed brakes fit snugly against the fuselage sides, just aft of the wing, on the first DC-8, but will be replaced in due course by thrust brakes on the engines.

Below, a rear view of the suppressor "daisy," developed according to Rolls-Royce theories. This installation is still in prototype form.

Below, a close-up of the starboard main undercarriage. The rear pair of wheels castor when the nose-wheel is steered through more than 45° either way.



The Hard Commercial Facts

LAST month B.O.A.C.'s managing director issued a message to the Corporation's staff which stated, very clearly and concisely, the facts of commercial life.

The message had followed the announcement of the Corporation's loss of £2.75 million in the 1957-58 period and explained some of the reasons for this loss and the need for greater efficiency and economy. After saying that there were reasons for believing that the results would be better in 1958-59, Mr. Basil Smallpeice went on:—

"Now you may ask: why should we be concerned if our financial margin is a narrow one? Isn't it sufficient for us to scrape home and avoid a deficit? Well, one reason is that we then have absolutely nothing in hand to cushion the effects of any temporary falling-off in traffic—so that if that occurs we promptly go into deficit and cease to pay our way; moreover, a chain of inquiry starts, to establish causes and culprits, which is disturbing and painful for everybody. Another reason is that we have nothing in hand to absorb special cost shocks, such as those we have experienced in introducing new aircraft types. A third reason is that it is in any case almost impossible to forecast accurately, however hard one tries; and it is only common-sense to provide sufficient margin to absorb a possible error. . . .

"But, perhaps most important of all, we have no money in hand to finance expansion of business and development of new routes. I do not mean the money required to buy new aircraft or erect new hangars—that kind of capital can be raised by stock issues, or in our case at present by obtaining Exchequer advances. I mean, rather, the money required to cover the operating losses which always arise in any transport undertaking (or nearly always) in the early years of extending services or opening new routes—money which, subsidy being ruled out, can only be acquired through earning profits and retaining them in the business. If we are to extend our operations across the Pacific to Japan and to Australia, and if we are to get back on the South American route, and if we are ever to open up operations across Russia to the Far East, we must have sufficient profit margin in hand to be able to afford their initial losses.

"Other airlines can do it. So why can't we? And the answer is that our costs are too high—measured against comparable airlines. Therefore, unless we can get our costs down to their levels, we shall never be able to grow as vigorously as they can and do.

"As I indicated in my letter of last September, the main reason why our costs are too high is that we spend about twice as much as comparable foreign airlines do on maintenance of aircraft, for the same volume and quality of work."

Mr. Smallpeice then explained the series of events which, since 1950, had led to the fact that costs had been growing and how studies were made of the causes for this growth in rising expenditure. He outlined the way in which these problems had been explained to the engineering staff through the normal consultative channels. He went on:—

"The objective of this process of joint consultation is to enable the Corporation to catch up with its competitors in efficiency, and regain the ability to expand and develop as they do. It is not enough to be provided by the Government with capital to buy new aircraft; in order to grow, we also need to produce seat-miles and ton-miles as cheaply as any of our competitors. And this must be done reasonably quickly; the rearrangements involved are necessarily complex and will therefore take time, but we should aim to get on level terms with our competitors by about two years from now—no easy task. . . .

"What has happened since 1950 is that centralization and new methods have become possible in airline engineering—and are adopted by our main competitors. We cannot escape the necessity to adapt ourselves. . . ."

Eland-Convair Progress

SINCE the Eland-Convair 340 arrived in Santa Monica at the end of last year, the Napier team have been making steady progress toward American certification. We recently had a chance to obtain some information on the spot from Mr. K. Greenly and Mr. M. J. Randrup, respectively the company's project manager at Santa Monica, and chief test pilot.

Up to the end of May, 150 hours had been flown in the C.A.A. programme, covering performance, flying qualities and powerplant tests. Probably less than 50 hours remain to be flown to complete these portions of the tests, plus a further period for functional and miscellaneous flying.

The trials are being based on Santa Monica, where PacAero (a division of Pacific Airmotive) is responsible for future conversions of Convairs to Eland power; but most of the take-off and landing trials have been made at Palm Springs or Edwards Air Force Base, where more space is available. Napier have had as many as two dozen engineers at Santa Monica to handle certification and to acquaint PacAero with the Eland, but the size of this team is now beginning to run down as the certification target date of September approaches. Mike Randrup has been in charge of all the flying, assisted by the PacAero pilot and with the C.A.A. pilot participating in most of the trials.

The Eland-Convair is among the first aircraft submitted for certification under the requirements of SR.422 and SR.423—the C.A.B. amendments to C.A.R. 4b relating to turbine-powered aircraft and piston-engined conversions. Consequently Napier have felt themselves to be guinea-pigs in some respects, although they have established cordial relations with the C.A.A. The aircraft itself is substantially the same as when first flown except that it now has automatic starting using a Napier-developed automatic control unit. Production conversions will have Eland 504A engines, with provision for air starting, using a Blackburn Palouste air-generator if required by customers.

Before the type certificate is obtained, the Convair 440 conversion, now in the shop at Santa Monica, should be ready, and this is to be leased to the R.C.A.F. for familiarization prior to delivery of the Canadair-built CL-66s. The latter, incidentally, will carry an additional 240 Imp. gal. of fuel and will be cleared by the R.C.A.F. to operate at 57,000 lb. compared with the commercially approved weight of 52,500 lb. After completing this 440 conversion PacAero will prepare to receive the first of the three REAL Aerovias Convairs, which will each spend 45 days at Santa Monica undergoing conversion.

The Eland is expected to start its commercial life with an overhaul period of 400 hours, which will be built up as more hours are accumulated. The Elizabethan test-bed is now being fitted with Eland 504A engines and will be devoted to endurance flying.—F.G.S.

Photographs copyright "The Aeroplane"

The Eland-engined Convair 340 photographed at Santa Monica early this month and, right, a close-up of the triple-cluster Lockheed camera installation under the fuselage used in take-off and landing tests.

THE FIGHTING SERVICES

Birthday Honours

A SUPPLEMENT to the *London Gazette* published on June 12 included the following Birthday Honours conferred by Her Majesty the Queen:—

ORDER OF THE BATH (Military Division)

As Companions

Air Vice-Marshal H. R. Graham, C.B.E., D.S.O., D.F.C.; Acting Air Vice-Marshal L. M. Corbet, C.B.E., M.B., B.S., R.A.F. (Retd.); Air Commodore H. H. Chapman, C.B.E., A.M.I.E.E.; Air Commodore K. J. McIntyre, C.B.E., R.A.F. (Retd.); Air Commodore W. A. Stagg, C.B.E.; Air Commodore W. P. Sutcliffe, D.F.C.; Acting Air Commodore W. S. Gardner, O.B.E., D.F.C., A.F.C.; Acting Air Commodore J. A. Tester, C.B.E., R.A.F. (Retd.).

ORDER OF THE BRITISH EMPIRE (Military Division)

As Dames Commanders

Air Commandant A. M. Williamson, R.R.C., Q.H.N.S., P.M.R.A.F.N.S.; Air Commandant M. H. Barnett, C.B.E., A.D.C., W.R.A.F.

As Commanders

Air Commodore D. A. Wilson, A.F.C., M.R.C.S., L.R.C.P., F.F.R., D.M.R.E., D.M.R., Q.H.S.; Group Captains R. F. Aitken, O.B.E., A.F.C.; R. J. B. Burns, O.B.E.; E. C. Harding; L. M. Hodges, D.S.O., O.B.E., D.F.C.; S. W. Lane, M.B.E., A.M.I.Mech.E., A.F.R.Ae.S.; T. W. Piper, O.B.E., A.F.C.; D. D. Rogers, O.B.E.; F. W. Stannard, R.A.F. (Retd.); M. C. R. White; Acting Group Captain W. A. Hammerton.

As Officers

Wing Commanders R. A. Colville; P. C. Dainty, M.B.E.; H. H. C. Hester, A.F.R.Ae.S.; J. C. Hunter; S. R. Hyland, D.F.C., A.F.C.; F. Lathan, M.D., Ch.B., B.Sc.; J. L. Lendrem; T. A. M. Pritchard; A. C. Rawlinson, D.F.C., A.F.C.; R. D. Romanis; R. L. Smith; J. H. Stevens, B.Sc.; R. H. Whipp; Acting Wing Commanders C. E. Cahill; G. E. Winn, R.A.F.V.R.; Squadron Leaders A. Bruce; A. G. Douglass, A.F.C.; J. Gale; D. R. Locke; D. T. Stanley.

No. 152 Squadron Disbandment

A DISBANDMENT parade of No. 152 (Hyderabad) Squadron, attended by the A.O.C., No. 11 Group, is to be held at 11.00 hrs. on July 11 at R.A.F. Stradishall, followed by lunch in the Officers' and Sergeants' Messes, and the N.A.A.F.I. Ex-members of all ranks are welcome to attend and are requested to write, without delay, to the Squadron Adjutant, R.A.F. Stradishall, Newmarket, Suffolk.

Malaya Air Force

AIR COMMODORE N. C. HYDE, C.B.E., is to take up the appointment of Air Officer Commanding of the new Federation of Malaya Air Force this month. For the past few months its formation has been going on under Air Cdre. A. V. R. Johnstone, D.F.C., who left the Air Staff at Headquarters, No. 224 Group, Malaya, to become the first A.O.C.

Commandant of the Central Flying School, R.A.F. Little Rissington, since January, 1956, Air Cdre. Hyde previously served in Germany and Bomber Command.

No. 60 Squadron

BASED at R.A.F. Tengah, Singapore, No. 60 (Fighter) Squadron will, on July 6, have completed 10 years' operational flying against the Malayan terrorists, and 38 years' service in the Far East. Commanded by Sqn. Ldr. A. F. Jenkins, No. 60, the senior operational squadron in F.E.A.F., has since its posting to Malaya flown 5,317 sorties against the terrorists and logged 5,228 operational flying hours. It is equipped with D.H. Venom F.B.4s.

Founded at Gosport on April 30, 1916, No. 60 Squadron first saw action in June, 1916, then equipped with the French "Moraine Bullet." Captain (later Air Marshal) W. A. Bishop won his Victoria Cross with the Squadron, and Capt. Albert Ball, V.C., gained his D.S.O. and three Bars while serving with it. Disbanded in 1920, the Squadron was re-formed the same year at Lahore, and has since been continuously on duty in the Far East. It is unique in having almost been continuously engaged in operations since its formation, and always overseas—France, India, Burma and Malaya.

University Air Squadron Camps

SUMMER camp training for members of the 17 University Air Squadrons started on June 15 with the squadrons of Cambridge, Edinburgh and St. Andrews moving to R.A.F. Syerston, Hemswell and Lindholme respectively. All squadrons, divided into two sections, will attend camps in the period from June 15 to July 13.

Of the remaining University Air Squadrons, Aberdeen and Birmingham are going to R.A.F. St. Mawgan; Bristol is moving to R.A.F. South Cerney; Durham to R.A.F. Martlesham Heath; Glasgow and Manchester are flying to R.A.F. Thorney Island; Hull and London are going to R.A.F. St. Eval, and Oxford is moving to R.A.F. Hullavington.

R.A.F. Appointments

THE following are among recent Royal Air Force appointments:—

Group Captains: C. J. G. Ferguson to the Air Ministry for duty in the Department of the Air Member for Supply and Organization; W. T. H. Nicholas, O.B.E., to S.H.A.P.E. for staff duties.

Wing Commanders: F. E. Ludgate to the Air Ministry for duty in the Department of the Air Member of Supply and Organization (with acting rank of Gp. Capt.); A. Ashworth, D.S.O., D.F.C., A.F.C., to the Ministry of Supply, Boscombe Down; L. H. Bartlett, D.S.O., to Headquarters, British Forces, Arabian Peninsula, for air staff planning duties; J. F. J. Dewhurst, D.F.C., A.F.C., to R.A.F. Cranwell to command the Flying Wing; A. J. J. Kirk to Allied Air Forces, Northern Europe, for staff duties; G. L. Mattey, D.F.C., A.F.C., to Headquarters, Coastal Command, as Staff Officer to the Commander-in-Chief, Home Fleet; J. Quinn, D.F.C., to Headquarters, Amphibious Warfare, for staff duties.

Squadron Leader L. A. A. Butler to the Air Ministry for duty in the Department of the Chief of the Air Staff (with acting rank of Wg. Cdr.).

As recorded on this page, No. 60 Squadron will have completed 10 years' operational flying against the Malayan terrorists next month. Seen flying in typical Singapore cloud conditions are three of the Squadron's Venom F.B.4s, based at R.A.F. Tengah.

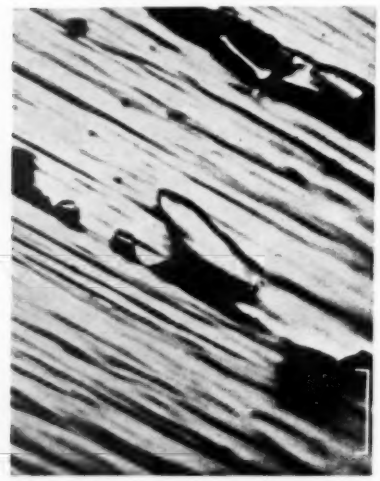
Materials and Processes . . . .

Metals and Aeronautical Engineering

By Prof. A. J. Kennedy,* Ph.D., A.M.I.E.E., F.Inst.P.

FLIGHT, with its attendant technologies, has always provided a major stimulus to materials development. The intensive research of the past 20 years into the nature and properties of metals has grown up largely because of aeronautical demands. At the present time, nuclear energy constitutes a second major force in driving forward the development of new materials, but even in this field aeronautics has an obvious long-term interest, and will ultimately bring its influence to bear on the course of material design.

The general nature of the conditions which more advanced aircraft and missiles will impose upon the metals of their construction is well known. Higher speeds result in kinetic heating; surfaces and structures may be expected to encounter high local temperatures—over 300° C. at Mach 3; greater speed in manoeuvres and greater accelerations give rise to greater stresses; more powerful propulsion units require higher working temperatures. Thus, taken together, the problems of such effects as deformation, corrosive deterioration, failure by creep or fatigue, heat dissipation and thermal shock provide a combination of difficulties on a totally unprecedented scale.



A micrograph showing extrusion at the slip bands in Duralumin during fatigue.

In addition, the materials, however excellent, have still to be fabricated, shaped, joined and assembled. It will be evident that the whole future of air or space vehicles, whatever form they may take, is linked to the evolution of materials capable of fulfilling the theoretical designs. There is no other limitation to advancement quite as fundamental as this; other problems exist, but most would reduce to reasonable dimensions were the ideal material at hand.

An appreciation of the advances that metallurgical science and the various related technologies have achieved demands some general acquaintance with the basic features of metallurgical structure. Useful metals are very complex affairs. They are built up of crystals of different composition and atomic arrangement, each such crystal being in itself a quite complicated unit. The atoms that make it up are never exclusively of the same element and the special arrangements of these different atoms, controlled by the nature of the interatomic forces and by statistical laws, result in partly ordered, partly disordered, patterns of considerable complexity.

In places, aggregates of atoms group in particular arrangements to form what are known as precipitates. Even where a local uniformity in composition exists, the structure is still not perfect, and consequently a number of types of defect, for example, vacant sites (missing atoms) or dislocations (regions of lattice misfit) abound. The dislocations, which are generally fairly mobile under stress, in fact largely dictate the overall mechanical properties.

When it is realized that this complex of structures and substructures can give rise to a great variety of separate distinctive processes, each dependent on stress, temperature and local atomic arrangement in its own particular way, it is hardly surprising that solid-state physics is still struggling to understand the diverse phenomena which can arise. An improved fundamental understanding is an inherent part of the metallurgical advances of recent times and in many ways the more logical picture of metallic behaviour which has been put together since the late War is more significant in its implications for the future than the more apparent technological achievements, remarkable though some of these may be.

ALLOYS FOR INCREASING TEMPERATURES

Increased operating temperatures arise in two main ways: in skins and structures at very high speeds, and in the components of more powerful jet engines and rocket motors. Each presents its own special difficulties, and each has been met partly by the improvement of already well-developed alloy systems, and partly by the establishment of quite new types. It is convenient to consider the various classes separately.

Traditional high-temperature alloys

The traditional high-temperature alloys have been based on one or other of the four elements: iron, nickel, cobalt or chromium, in various combinations, and usually with a number of added elements. There is no doubt that the achievement of speeds in the region of Mach 1 has been due to the production of superior alloys of this type; notably the nickel series, as exemplified by the Nimonics.

Jet engine progress has been strongly associated with the resistance of these nickel alloys to deformation at working temperatures in the range 800-900° C. The general principle operating in their development is that of strengthening the solid solution of nickel and chromium by additions of cobalt or molybdenum, at the same time achieving finely distributed precipitates by the addition of other elements, notably titanium

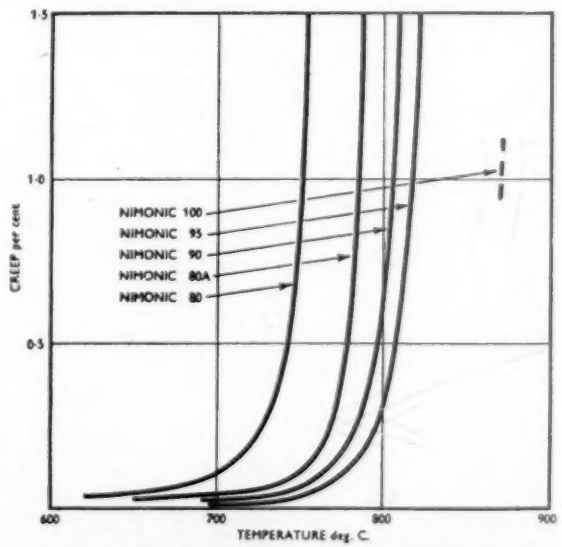
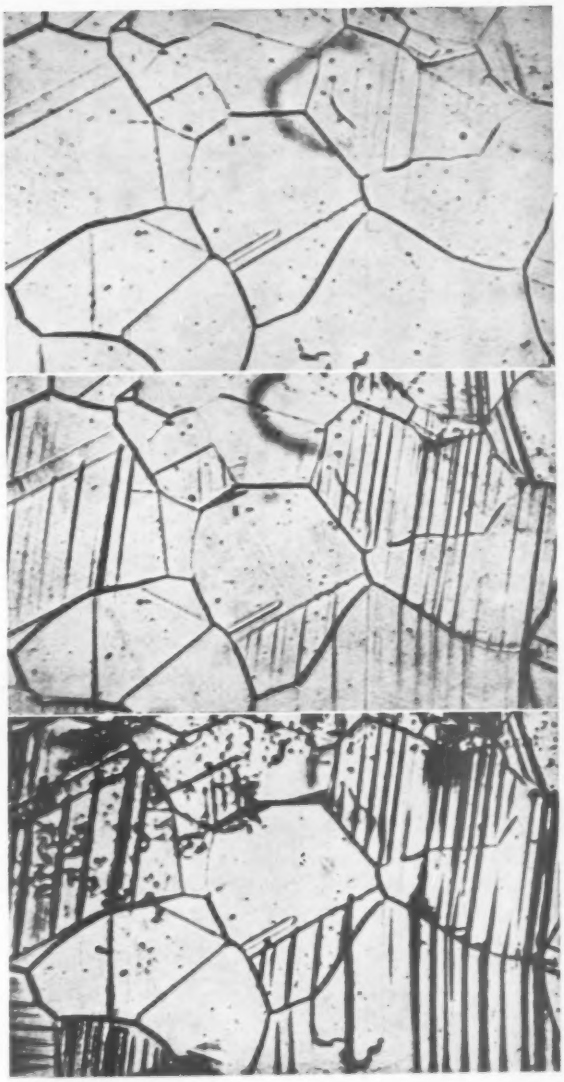


Fig. 1. The 100-hr. creep strain of Nimonic alloys under 12.7 tons/sq. in. plotted against test temperature.

* Professor of Materials and Metallurgy, College of Aeronautics.



Pure nickel in fatigue—330 magnification. Top to bottom, after 10,000 cycles, 50,000 cycles and 270,000 cycles.

and aluminium. The later editions of the Nimonic series (90, 95 and 100) have higher titanium and aluminium contents, and introduce about 20% cobalt at the expense of nickel—and at the expense of chromium as well in the case of Nimonic 100, which also has additional molybdenum.

These stronger materials are considerably less hot-workable than their predecessors, and it is only because a suitable hot-extrusion process became available at the right time (the Ugine-Séjournet glass-lubrication process) that these more creep-resistant alloys have become a practical possibility. A life of about 200 hr. at 6 tons/sq. in. and 940° C. is achieved with the best of these alloys and some further improvement may be expected in the future which may well edge the useful working temperature up nearer to 1,000° C.

It is unlikely that this type of alloy will go much further. Its importance, however, will remain for applications in the temperature band for which it was designed. The general usefulness of the Nimonics has been widened by the appearance of casting versions of the alloys, which have been taken up for stator blades and for nozzles, as, for example, in the Bristol Olympus and Proteus engines. The revival of interest in castings generally is a feature of the past 10 years and will be specially discussed later.

The earlier Nimonic 75, an 80-20 Ni-Cr alloy strengthened by distributed carbides of titanium, is reasonably ductile at the conventional temperatures of forming and shaping and is highly oxidation-resistant. It is therefore extensively used as a flame tube and afterburner material. The more recent development of a sandwich sheet in this alloy (with a copper layer) enables it to be seriously considered in assemblies with local hot spots too high for the straightforward Nimonic 75. Inconel, a 76-15-8 Ni-Cr-Fe alloy with a high corrosion resistance, now finds wide application in jet-pipe insulating blankets made up as sheet foil with an internal layer of silica fibre, and in other components where high-temperature oxidation would seriously affect other alloys.

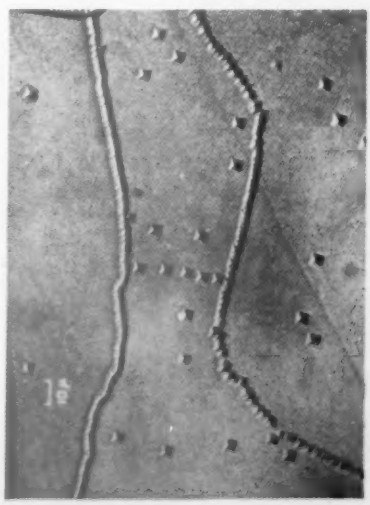
The highly critical nature of the creep working temperature of these alloys (and, indeed, of all high-temperature materials) is brought out by Figure 1. It will be seen how strikingly the creep resistance has been improved by the judicious introduction of additional elements and by the control of heat-treatment. Indeed, a characteristic of most of the newer precipitation-hardened alloys is their high sensitivity to heat treatment.

An adequate discussion of the merits of the Nimonics, in relation to propulsion technology, is not possible here. They dominate the jet engine scene at the present time and although the need for a higher-temperature alloy for certain components is now pressing, some place for them in high-temperature machines seems assured.

Alloys of cobalt have been jostling the Nimonic alloys for some time. Some of these alloys are already in widespread use—the 60-30-6 Co-Cr-W alloy, for example, is now used considerably as a casting material for turbine blades. The cobalt alloys achieve their creep resistance by a dispersion of carbides, and consequently carbide-forming elements, such as niobium, tantalum, molybdenum and tungsten are added. As distinct from the Nimonics, their properties are adversely affected by solution heat-treatment and by quenching. A more recent factor is the effect small additions of boron or zirconium have on the creep and ductility of vacuum-melted cobalt alloys: considerable improvements are reported—something like twice the life under comparable conditions. These same elements have also been introduced beneficially into steels. The cast cobalt alloys possess excellent oxidation resistance at high temperatures, but they are costly.

The high-chromium alloys, which offer rather special difficulties of preparation, have always appeared to have something in hand over the alloys or iron, or nickel, or cobalt, as the melting point of chromium (1,950° C.) is several hundreds of degrees higher than those of the others. Embrittlement is the most pronounced problem. Alloys of high strength have been produced, such as the 60-25-15 Cr-Mo-Fe, and others with even higher chromium, but they are handicapped by sigma-phase embrittlement. So far as strength is concerned, it appears likely that such alloys may possess a greater tensile strength at 1,000° C. than any other available at the present time—including the forged cobalt and the Nimonic alloys—but in practice their use in dynamically stressed components may be limited until better ductility is achieved.

The iron-base alloys—the austenitic and ferritic steels—have developed distinctively in strength and creep resistance, largely by a closer measure of control in treatment, and by added elements. A conventional austenitic 18-8 Cr-Ni stainless steel can, for example, approximately double its high-temperature rupture strength, say in 1,000 hr., by the addition of fairly small amounts of molybdenum, tungsten, niobium and tantalum. With these additions, the amounts of chromium and nickel are adjusted so that a stable austenitic structure is retained, with



Etch-pits at dislocations in a lithium fluoride crystal.

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a strong dispersion of refractory carbides or intermetallic compounds.

These alloys are very sensitive to heat treatment, which can affect the creep life by a factor of 10 or so. Most austenitic stainless steels precipitate carbides from 500° to 700° C. and under certain corrosive conditions severe intergranular oxidation can occur.

The 17-7 Cr-Ni steels, with about 1% aluminium, have come forward strongly as a suitable precipitation-hardening sheet material for aircraft skins at service temperatures up to 450° C., particularly in association with honeycomb structures. Their great merit is that they combine a high strength/weight ratio with good forming properties, and they are now used extensively in the faster military aircraft.

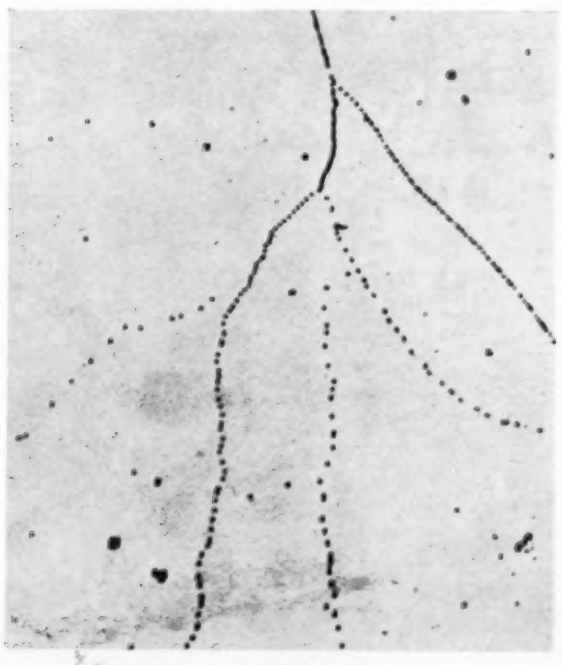
Recently, a new heat treatment for this steel has been reported involving cooling from 950° C. to −70° C., and the consequent establishment of a martensitic structure, which leads to yield strengths of about 100 tons/sq. in. at room temperature. The alloy appears to offer a very excellent balance between the requirements of fabrication and high-temperature strength.

Generally speaking, with the ferritic steels, the lower temperature transformation structures (such as the bainites and martensite) are preferred, from the creep-resistance point of view, under conditions of short-duration stressing at what might be called the medium temperatures. At the higher working temperatures, the pearlitic structures offer better performance.

With the straight chromium steels the martensitic grades (usually with from 11.5% to 14% Cr) are generally more useful than the ferritic grades, at the higher temperatures around 600° C., as they are not subject to the temper embrittlement of the ferritics, and they are harder. Welding, however, is more difficult. The 5% Cr steel (0.4% C) has proved itself as a structural material at temperatures as high as 550° C., and again has applications in honeycomb construction.

The increased use of aluminium in steels is noticeable. In fact, aluminium increases the oxidation resistance of the iron-base alloys more than an equivalent amount of chromium, and the thermenol alloys (18-4 Al-Mo) are now a very possible compressor blading material. This material has a rupture life at 650° C. over 50 times greater than an average stainless steel at a stress of 6 tons/sq. in. The initial difficulties arising from grain growth at higher temperatures (the alloy is a single phase material) appear to have been largely overcome by small additions of zirconium (0.1%) and carbon (0.4%).

This abridged review of the more traditional lines of metallurgical advance cannot do justice to all that has been done in advancing the field of application of these alloys. It is evident that great improvements have been possible by a closer control of alloying; by more exact heat treatment: by purer base metals; by the addition of a wider range of elements, and by new methods of fabrication. It is unlikely, however, that this class of alloy will ever sustain useful engineering stresses much above 950° C., and we may therefore think of 1,000° C. and beyond as being a range requiring a quite new approach. This does not detract from the valuable part these alloys will play in applications which, at the present time, are satisfactorily fulfilled by the lower-temperature materials.



Etch pits at the ends of dislocations in silicon iron.

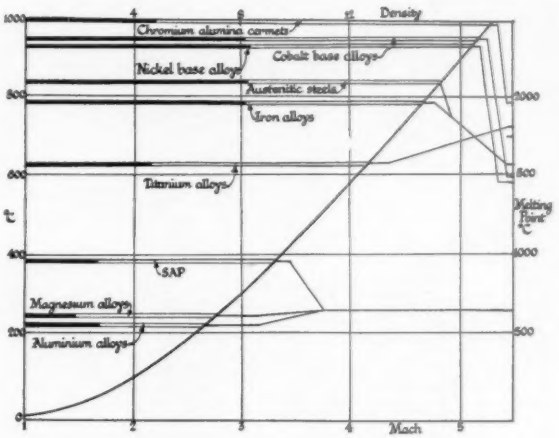


Fig. 2. This curve shows the variation of surface temperature with speed for an ambient (stagnation) temperature of −50°C. The limiting useful working temperature for various alloys is shown, the respective densities being indicated by the thick lines measured against the top scale. The actual melting points of the base metals are given by the right-hand scale, as indicated.

Light alloys for higher temperature service

For surface temperatures of about 200° C. at Mach 2 (at 30,000 ft.) the present alloys of aluminium appear to be capable of sustaining the working stresses. Above this speed the temperature increases rapidly to about 550° C. at Mach 3.5 and unless special methods of surface cooling are applied (and this certainly appears desirable anyway) the aluminium alloys will not be practicable. Radiation, incidentally, becomes a very important means of cooling at high temperatures, and the question then arises of obtaining high emissivity, possibly by the application of nickel-alloy coatings.

For our present purposes we may consider alloys for use over this range of conditions as representing high-temperature structural materials, as distinct from high-temperature propulsion materials, although it is evident that ultimately, say at Mach 4.5, when the surface temperatures may be around 800° C., we enter the range of the present engine alloys and such a distinction disappears. Fig. 2 summarizes the factors entering into the kinetic heating question, and shows the approximate limitations of various alloys.

At the present time the alloys based on titanium appear to be the most promising of the new structural materials, in spite of their low working temperature compared with the melting point of titanium (1,800° C.). In this they are well below the average for metals in general.

Although expensive, titanium alloys have been widely taken up, particularly in military aircraft, for skins and bulkhead assemblies, and also for compressor blades and cases. It can be brazed, plated (which makes it possible to improve its poor electrical conductivity) and chemically milled. At present its strength at higher temperatures is not high enough—a figure of at least 6 tons/sq. in. at 650° C. is really required.

Although its use as a bolt material is gaining ground, the demand for titanium by manufacturers has been smaller than was anticipated—possibly by a factor of 20. The reason is simply that the extra benefits that titanium bestows, taken in relation to its cost, are not striking except under very particular circumstances. Up to 550° C. the oxide skin which forms prevents further oxidation, but above this the metal absorbs the oxide and embrittlement results. However, when the metallurgy of the titanium alloys is better developed, we may expect higher temperature applications, possibly as high as the required 650° C.

Because of its high reactivity (there is no known resistant

(*Continued on page* 851)

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(*Continued from page* 850)

refractory) the metal is usually melted by a direct current arc in a water-cooled copper crucible in an inert gas atmosphere or *in vacuo*. There are hazards associated with this process, and considerable protective measures have to be taken. Hot-rolling of the alloys is straightforward, but the more extreme cold rolling (as for thin sheet) of the higher strength alloys, has proved impossible. Creep resistance has also caused some concern, as has the high ratio of proof stress to ultimate.

It may be useful to state briefly the range of alloys available at present. Titanium transforms on heating up through 882° C. from the alpha form (hexagonal) to the beta form (body-centred cubic). In order to stabilize one or other of these forms other elements are added, and alloys which are wholly alpha, or wholly beta, or mixtures of both, may be obtained. The stronger alpha alloys are the difficult ones to fabricate (5% Al 2.5% Sn.).

The all-beta alloys, while softer, have a lower creep resistance and tend to be unstable and brittle at the higher temperatures. The beta alloys are not in commercial use at the present time, although their high corrosion resistance (as in the 30% Mo alloy) may offer future uses. The alpha-beta alloys, when heat-treated, combine ductility and strength. The beta phase is stabilized by additions of such metals as manganese, niobium, molybdenum and tantalum and the alpha phase is strengthened by the addition of one or other of the few elements that show any appreciable solubility in alpha-titanium, such as aluminium, tin or zirconium.

For high-strength forgings eutectoid forming elements such as chromium have been added; the highest strength so far achieved (about 90 tons/sq. in.) appears to be that exhibited by an alloy of this type (5% Al 1.3% Fe 1.3% Cr 1.3% Mo) but at the price of ductility. The best hopes for the future appear to lie in the development of an alpha alloy with a finely dispersed intermetallic compound such as might arise from tempering a suitable martensitic alpha phase.

To sum up on titanium: the main obstacles to its greater employment in aircraft are cost, the difficulty of fabricating the high-strength alloys, the suspicion that it may be sensitive to fretting fatigue, and the limited work-hardening range. In spite of these real limitations, the development of the titanium alloys is a metallurgical achievement of great merit and of considerable significance to aeronautics.

Aluminium alloys have also come forward in temperature application. In particular, the sintered aluminium—aluminium oxide powder (SAP)—has shown superior creep properties, at temperatures above 300° C., to the wrought alloys. SAP is simply a compact of oxide-coated particles with up to as much as 20% oxide. Apart from the fact that this alloy has certain distinctive advantages, which are not by any means properly exploited at the present time, it does indicate what can be achieved by the right introduction of a stiffening constituent into a fairly ductile matrix.

Magnesium has returned to favour as a structural material, being cheap, plentiful, light (density 1.8) and readily cast. The newer alloys, containing 4% thorium with a little zirconium have proved to be highly creep resistant at temperatures at least as high as 300° C., and there is a fair expectation that alloys useful up to 370° C. will be forthcoming. The improvements in castings, giving thin-walled, high strength parts have been notable—for example, the addition of 10-15% lithium raises the yield point to over 20 tons/sq. in., but at the expense of corrosion resistance.

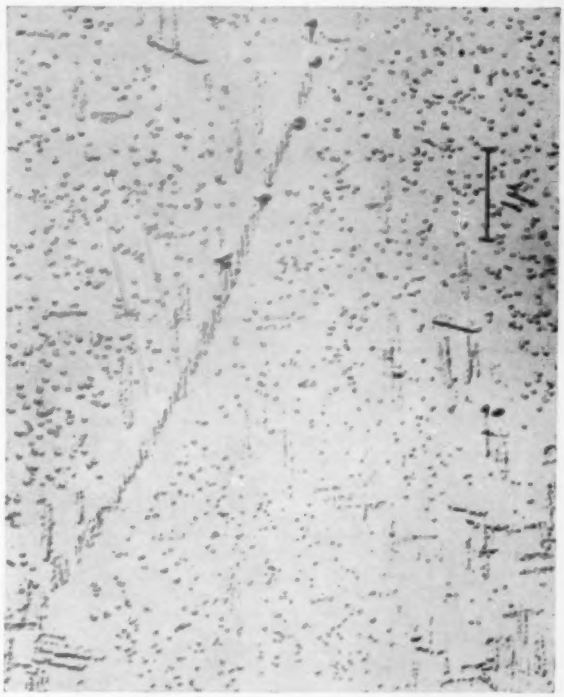
Spheroidal graphite (S.G.) cast iron is also admirable for high-precision intricate castings. It has a much superior strength and toughness, compared with normal cast iron, by virtue of the spheroidization of the flake graphite. Both ferritic and pearlitic structures can be obtained, and each have useful features. By adding nickel and molybdenum a high-strength acicular structure is obtained.

This material has been widely taken up by a variety of industries, but not, apparently, until fairly recent times by the aircraft industry. A number of uses are now being found for it, including a hot air control valve casting which is required to work at 400° C.; the properties of S.G. cast iron have enabled the weight to be reduced to the minimum.

New types of alloy for very high temperatures

A number of elements have melting points far higher than those of the metals used at present (tungsten, for example, melts at 3,400° C.), but for various reasons no advantage can, as yet, be taken of the margin these metals offer, with the possible exception of molybdenum, now the subject of intensive research.

Molybdenum has all the necessary strength at temperatures in the range 900°-1,300° C. but is handicapped by catastrophic oxidation, by limited ductility arising from grain boundary



An electron micrograph of precipitation structures on individual dislocations in Duralumin.

contamination and by its brittleness in welding. A very small amount of oxygen, two parts in a million, is sufficient to produce a serious effect on the properties. Purification of the metal improves the ductility, as do additions of titanium. The welding strength can be improved to a certain extent by hot-working and more distinctively by inert-atmosphere welding.

As far as oxidation-prevention is concerned, the most obvious course is to develop a protective coating with the necessary adhesive and heat-resistant properties. Using chromium or nickel-chromium plating, protection up to about 1,100° C. is reported, but to go beyond this will almost certainly require a coating of the molybdenum disilicide type (this important material is discussed later).

The superiority of the arc-cast molybdenum alloys (there are four basic kinds involving, respectively, alloying with a little niobium, titanium, vanadium, or tungsten) is striking—particularly that containing 0.45% titanium. (Arc-cast molybdenum, is, incidentally, preferred to the powder metallurgy product.) For example, at 900° C. the 100-hr. rupture strength of this alloy is very nearly three times higher than the best of the nickel or cobalt alloys.

As might be expected, the question of a suitable protective coating has been, and is, the subject of exhaustive study. The specifications for such a coating are extremely rigorous and the best that can be said is that beyond 1,300° C. no satisfactory coating has been produced that is not sensitive to thermal shock or to high stresses.

Its possible applications in the missile and aircraft field are prodigious. It has a usefully high elastic modulus (and consequent high buckling resistance), high thermal conductivity, low coefficient of expansion, and high erosion resistance, and it can be fabricated by most standard methods. A successful coating or other oxidation-resistant modification could result in an immediate advance in the power developed by present jet designs.

Niobium is also a very possible high-temperature metal, and it may be easier to improve its oxidation resistance than in the case of molybdenum, because the oxide formed (Nb_2O_5) is refractory as compared with the volatile MoO_3, and by the addition of alloying elements it may be possible to form a reasonably stable niobate coating.

Apart from molybdenum, and the other theoretically possible hard metals, two main types of material have been produced to meet service temperatures of around 1,000° C., cermets and intermetallic compounds. The cermets, which are mixtures of ceramics (beryllium and aluminium oxide, for example) and

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metals, are designed to combine the virtues of high-temperature strength with those of reasonable ductility.

The original alloys were largely ceramic, with about 30% metal, but the converse has also been tried with great success so far as creep resistance is concerned. Only one per cent. of added zirconium oxide doubles the life of molybdenum under comparable conditions, 10% of alumina increases the life of nickel by a factor of over 600, and the 80-20 Ni-Cr alloys are improved by a factor of about 12 by only 1% of titanium oxide.

The metal carbides are generally considered as belonging to the cermet class, although strictly they should be classified with the intermetallic compounds discussed below. Titanium carbide is the most successful. Although it suffers from heavy oxidation about 900° C., and is relatively weak anyway at much above this temperature, when used with some other metal (such as nickel) as a binder, oxidation resistance, tensile and impact strength, and thermal shock resistance increase markedly. The series of alloys of this type offer about the strength-weight ratio of the nickel or cobalt alloys at 900° C.

The most significant development is the infiltration of a lightly compacted skeleton of fine particles, sintered at a low temperature, with a high-nickel alloy. This technique enables components to be constructed with the right kind of local properties; high strength (carbide) in the blade root, for example, and high metal in the blade edges improving the conductivity and ductility in these thin regions, as well as the oxidation resistance.

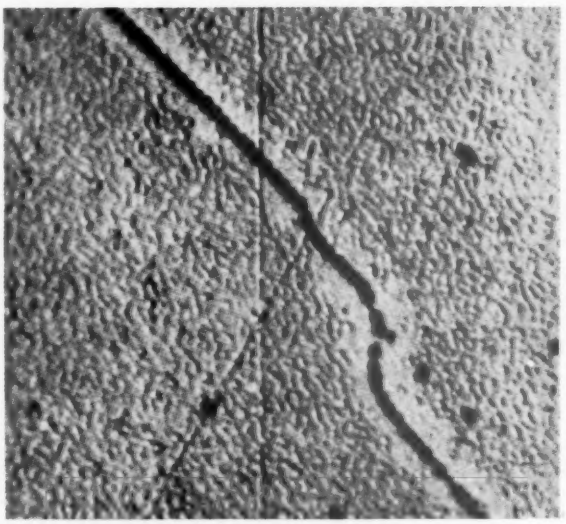
The intermetallic compounds include the borides, nitrides and silicides of the useful high-temperature elements, such as nickel and molybdenum. They are of fairly low density, and have superior thermal and mechanical shock characteristics compared with the straight ceramics, such as aluminium oxide. The borides (Zr B, for example) have a low resistance to oxidation, but are suited to short-term high-temperature applications, such as rocket nozzles.

It may be said here that successful coatings of straight ceramics have been achieved (the Rokide Process) by which an oxide such as zirconia, with a melting point of 2,500° C., has been successfully bonded to low melting-point metals. The silicides of titanium and chromium appear to have useful possibilities for similar applications, but, of all the intermetallics molybdenum disilicide is by far the most successful to date. Up to 1,650° C. it is resistant to oxidation attack by virtue of a protective film of silicon dioxide, and at 1,000° C. has a higher rupture strength than any of the present materials except the best molybdenum alloys. Its impact strength is, however, poor. Figure 3 demonstrates the range of application of the alloys discussed, based on 100-hr. rupture data.

ELECTRICAL MATERIALS AT HIGH TEMPERATURES

The increased heating of high-speed vehicles raises problems concerning the functioning of electrical components. Most present-day components can function satisfactorily in ambient temperatures up to 70° C. Raising this figure to 150° C. should not be difficult, with the possible exception of rectifiers, for which 100° C. appears to be a maximum. Germanium rectifiers, for instance, are limited to 80-90° C., but there is hope that tellurium rectifiers may function at very much higher temperatures in the 300-400° C. range.

Copper conductors must be protected from oxidation at high temperatures—by cadmium or nickel up to 150° C., or by nickel above this. Magnetic materials are naturally affected, but the Curie points of the useful alloys are high enough for all present purposes.



Dislocations forming a low-angle boundary in silicon iron.

Electrical requirements obviously raise very special problems, such as wire insulation (anodised aluminium as a cladding for copper seems possible in conjunction with a p.t.f.e. coating), capacitors and resistors, which cannot be adequately reviewed here. It may be sufficient to say that not all the requirements of a system for operation at 200° C. ambient temperature have been achieved, at least so far as reports indicate.

DEVELOPMENTS IN TECHNIQUES

The greater interest in castings is a noticeable change of attitude over recent years. Precision casting techniques have been much developed, largely based on conventional bonded-silica investment processes. The industry is also much more prepared to think in terms of large castings, particularly for engine parts in steel: the nickel-base alloys are generally rather more difficult.

Coupled with these developments has been a greater use of vacuum melting and casting, as well as casting in inert atmospheres. The effect of such processes is quite marked; the nickel-base alloys, for example, achieve an increase in working temperature of about 30° C., as well as a better fatigue life. It is evident, also, from the results obtained with the newer alloys, that much stricter control of composition is demanded, with much purer ingredient metals. This has led to greater concern about purification techniques (particularly significant in nuclear engineering) and the use of zone refinement techniques increases.

This technique involves the traversing of a solid rod of the metal by a molten hot zone which carries the impurities with it. After several such traverses a very pure metal is left. The technique can also, incidentally, distribute a required impurity uniformly. The method is usually specially associated with the purification of germanium for transistors, and their production is really due to its evolution.

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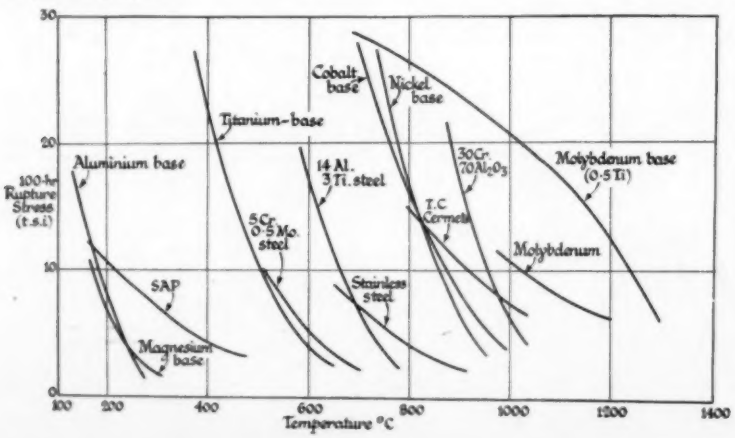

Fig. 3. The dependence of the 100-hr. rupture stress on temperature for various types of alloy. The exact curves depend greatly on composition and treatment and they should be taken to represent, approximately, the best in their class. The published information is not, however, wholly consistent.

Materials and Processes . . . .

(*Continued from page* 852)

On the powder metallurgy side, the distinctive possibilities of metal powder rolling have been demonstrated with stainless steel and with nickel. In this process, the powdered metal is rolled cold into final sheet form and then heat-treated. One advantage is that grain growth is almost eliminated (as compared with hot sintering). It is also a convenient method of cladding metal sheets with a second material.

Ultrasonic melting is a new technique which should have a good field of application in the aircraft industry. Most of the metals difficult to weld by conventional means—molybdenum, zirconium, nickel and stainless steel, for example—can be handled successfully. Spot welding is singularly suited to the technique.

DEVELOPMENTS IN KNOWLEDGE

While basic knowledge of the nature of metallic structure has grown considerably in the past 10 years, and has assisted, incidentally, the understanding of high-temperature behaviour, large parts of the subject are still highly conjectural. It is sometimes difficult to understand, at first sight, why, with knowledge of atomic behaviour so highly advanced in many fields, the mechanical behaviour of solids (particularly metals), which are after all merely assemblies of atoms, should prove so difficult to understand and predict.

There are, in fact, special reasons why atoms in the aggregate give rise to so many more diverse phenomena than they do as individuals, and why their modes of behaviour appear at times to be so arbitrary. All that can be said here is that we still remain in considerable ignorance of the fundamental nature of highly important practical effects.

At the present time, creep is reasonably well supported by theory, and much of the earlier empiricism in the subject—which has been thoroughly misleading fundamentally—has been replaced by sounder physical concepts. Fatigue theories, however, are sketchy and tentative, and fatigue prevention at the present time is largely a matter for engineering practice rather than for metallurgical design. It is hardly surprising, then, that under the complex conditions of stress and temperature which arise in aircraft structures and engines, the behaviour of the component materials cannot be predicted in any exact sense, and design is forced to make the best of our present rather imperfect and approximate methods.

Ideally, we require a detailed knowledge of the processes which can occur, of their interaction with each other, and of their net effects. All this involves difficult and extensive research, and must lead us to regard materials at higher temperatures as a complex of dynamic processes, which go forward under the applied conditions, and not as immutable materials defined by predetermined constants of one kind or another. The nature of the material changes continuously, leading ultimately to failure as a result of the combined effects of the separate but interrelated processes that occur.

This knowledge of metals and their nature is of high importance to aeronautics, as so much depends upon being able to design materials metallurgically, for specific conditions, and to design machines in terms of these materials within fairly accurately-assessed limits of behaviour.

In the future, considerable efforts will obviously be made to bring the high melting point elements, niobium, tantalum, rhenium, and tungsten, into service. The test case in the issue may well be molybdenum. If, by some device, this metal can be protected from oxidation under service conditions, and made into practical high-temperature components, then it may be that even higher temperature alloys will be realistic possibilities in 10 years' time. But the difficulties are not slight, and it may be many years before the molybdenum difficulties are overcome.

There is obviously going to be a big change in the way these special metals are prepared. The vacuum and high-purity techniques, the special methods of forming, are all going to make production much more like a laboratory process than it is at present. These newer alloys are delicate and sensitive things and will demand fine and precise metallurgical control, in keeping with their nature.

Although cermets are limited at the moment by brittleness, it has been possible to produce ductile refractory single crystals (magnesium oxide) which can extend by 20% without fracture, so we may expect improvements in this direction. Strength in materials is of course desirable, but not if this is achieved by reducing the ductility to vanishing point. The ultra-high strength steels, for instance, are being taken up very cautiously, although they seem now to be accepted in certain heavy undercarriage assemblies. Strengths up to 140 tons/sq. in. (at room temperatures) are now obtainable, and there is little doubt that this figure can be pushed even higher.

Theoretically, high strength can result from pinning down dislocations, or by their elimination from the crystal lattice. This second case has been achieved in certain very special types of fine crystal (whiskers), with diameters in the region of 30 micro-inches. These whiskers exhibit remarkable strengths; iron whiskers, for instance, have been grown with strengths of over 800 tons/sq. in. The reason is thought to lie in their high degree of crystal perfection, such imperfection as does exist being of an immobile type. While these whiskers are no more than academic playthings at the present time, research directed towards compacting them into a strong, reasonably ductile aggregate has highly practical objectives.

We see again in this case an example of the philosophy of two-component aggregates, already represented by the cermets, by SAP, S.G. cast iron and others. This assembly of strong units in an aggregate capable of deforming by their relative displacement is going to be (if indeed it is not already) a guiding principle in new high-temperature materials.

Another study which may prove fruitful in this context is that of fibre metallurgy, a technique by which wools or wires of high-strength metals—steels or the nickel alloys, for example—are randomly dispersed in a liquid medium and then bonded by sintering. This technique lends itself particularly to filtering and cooling applications.

For very short-time conditions of high stresses and temperatures, such as those that arise in missiles, much higher performances can be achieved than may be expected from the kind of data we collect about materials for more conventional aeronautical application. Heat treatments are here more important than alloying additions, and the object of the metallurgical design is to retain sufficient strength for very short times, even though a cataclysmic failure may follow very swiftly. Alloys in these applications are used in metallurgical states, which would be positively worse for longer term application, and it will be evident that a quite new subject has to be created, in both fundamental and applied terms.

Metallurgy and Nuclear Power

No review of metals in aeronautics can fail at the present time to take some note of nuclear power. The metallurgy of the important elements, uranium and plutonium for example, has been advanced beyond the wildest expectations in the past 10 years or so, as well as that of zirconium, an important structural material with a low neutron absorption cross-section, and of thorium, which on absorbing neutrons, transforms to a fuel.

Some of these elements have a complex structure and a complicated behaviour. Plutonium goes through no less than six phases when heated up to its melting point (640° C.), with large density variations of about 25% and, over some parts of the range, with a negative coefficient of expansion.

In addition to these difficulties, the whole subject of the effects of irradiation on metals is still in its very early stages, although the main results, the creation of vacancies in the lattice and the triggering-off of very high, very local, temperatures, are in themselves well established. The variety of the effects that may follow from these superficially simple mechanisms is, however, extensive.

Aeronautics is naturally greatly concerned with the possibility that such power may be made airborne. Such an achievement demands the reassessment of the present principles of nuclear power plants in terms of aeronautical factors, not least of which is that concerning the materials of construction. Special research into this field—at an early stage—is therefore vital. If materials limit the present propulsion possibilities, they will certainly exercise an even greater measure of restriction in the nuclear sphere.

Taking all the questions raised in this review together, it will be evident that materials enter into aeronautics in a very controlling way. Metallurgy and solid-state physics do not represent a service that can be drawn upon when things go wrong: they are part of the elemental information of design itself.

Aviation has enjoyed in the past a reasonable materials margin so far as strength and weight are concerned. This is no longer true. The limits now set by materials are of a much more far-reaching character, and only by a close alliance of aeronautical engineering with the materials sciences can they be properly appreciated and widened.

The principles of physical metallurgy should be as fundamental to the construction, fabrication and survival of the machines of the future (and, we may hope, of the present also) as are the principles of aerodynamics, thermodynamics, stress analysis or automatic control. All contribute to that fund of knowledge which aeronautical design demands and which, in turn, the practical ingenuity of aeronautical engineering transforms into reality.

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Materials and Processes . . . .

The Contribution of Plastics to Aircraft

In this article MR. C. W. WELCH, *assistant editor of our associated journal "Plastics" discusses the background of the development of plastics materials for use in aircraft and surveys their present aeronautical applications.*

IN the main, the plastics industry is a service industry. That is, it makes contributions to other industries, as is the case with metals, and only in specialized fields is it a producer of consumer goods in its own right.

With this principle in mind, the relation between the plastics and aircraft industries is clearly seen as one of supplier to customer. In common with radio, electrical engineering, ship- and boat-building, refrigeration and packaging, the aircraft industry is a potential or actual customer of the plastics industry. It is the purpose of this review to delineate the scope of the contribution of plastics to aircraft, and then to indicate the broad lines which this contribution will follow in the immediate future.

The Record to Date

Although the plastics industry had its origins in the commercial exploitation of gutta percha in 1850 and cellulose nitrate in 1870, it acquired an identity and momentum only in the early 1900s. Its birth and rate of growth is peculiarly similar to the motor and aircraft industries, all having developed in the present century. For the record, therefore, it is interesting to note that one of the first uses for cellulose acetate, immediately prior to and during the First World War, was as an aircraft dope for the treatment of fabrics. A rather specialized application for plastics in that War was the use of cellulose acetate sheet to construct an "invisible" aeroplane. At 1,600 ft., due to the transparent sheathing, the aeroplane virtually vanished from sight. The full facts came to light in 1941, in an issue of *Plastics*. A photograph of it was published in the *Illustrated London News* of January 16, 1916.

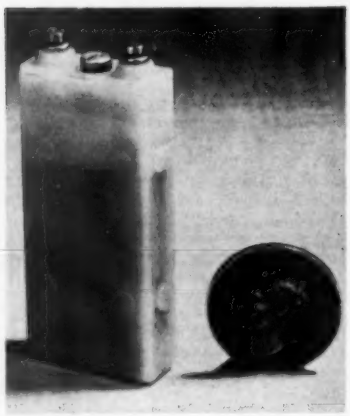
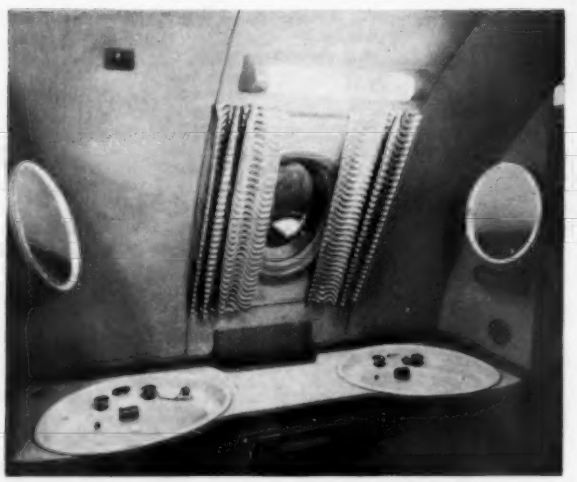


Fig. 1. Above, Nife Batteries Ltd. Ultra-lightweight battery.
Fig. 2. Below, Cobex (B.X. Plastics Ltd.) used in the Britannia.



Following this initial co-operation, the two industries largely went their own ways until the 1939-45 War. During the intervening period there had been intensive development in the light-metal industry to meet the needs of aircraft, whilst plastics technologists had gradually been extending the range of synthetic materials, first with phenolics, then ureas, and afterwards polyvinyl chloride, polythene, polymethyl methacrylate and others.

By 1939 the plastics industry was well established, producing in the U.K. some 30,000 tons of materials per year. In radio, electrical engineering, household wares, costume jewellery and in many other spheres plastics had established themselves on a firm basis. And with the War came an immense leap forward, both in consumption and research, so that today the U.K. industry makes some 400,000 tons of materials a year. Having a specific gravity of only one-seventh that of steel, this figure is, volumetrically, nearly 15% of the annual production of steel. Forward planning indicates that by 1961 the tonnage may be well in excess of one million.

By way of defining the terms which occur in this review, the reader who is unfamiliar with plastics materials may find it helpful to refer to Tables 1 and 2. The important plastics materials are here identified and although the data is not intended to be exhaustive, a broad indication is given of the present applications of the main materials.

In recent years the aircraft industry has been faced with a number of major problems, some of its own creation. With the introduction of the gas turbine (turboprop and turbojet), and now the rocket as prime movers, aircraft designers have been confronted with the task of developing structural units capable of containing these immensely powerful new engines. Metal fatigue and concomitant phenomena have delineated the limitations of metals and have forced the industry to look at other materials, including the synthetics. It cannot be said, however, that the search has been successful as yet. Plastics do not, at this point in time, offer an immediate solution to the problems of fatigue and temperature variations at very high-speed flight.

To assess the present contribution of plastics, therefore, it is necessary to divide the field into two parts—the first covering the actual usage of plastics today, mainly in passenger aircraft, and the second covering the potential usage in all aircraft, if certain lines of research pay off.

Present Uses

ELECTRICAL. It is in this field that plastics have made one of their biggest contributions. With the complexity of the electrical system of the modern aircraft, plastics have become

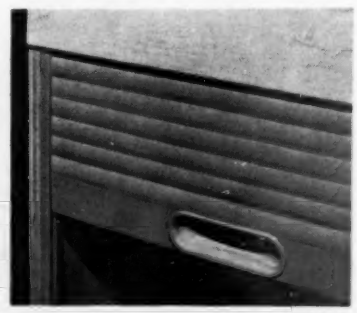


Fig. 4. Left, food storage cabinet shutter in Cobex.

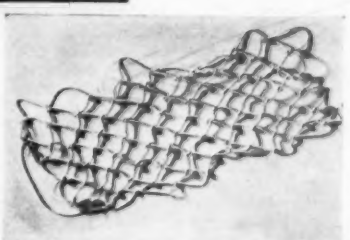


Fig. 3. Right, aircraft luggage rack in p.v.c. monofilament by J. F. Kenure.

Fig. 5. Glass-reinforced epoxy resin airbottle using Bakelite resin.

paramount. Insulation of wiring, encapsulation and insulation of radar equipment, printed circuits—all these are instances of applications of plastics materials because of their unique electrical characteristics.

Examples include Nyvin cable made by British Insulated Callender's Cables, Ltd., employing p.v.c. insulation over which is applied a glassfibre braid and a nylon sheath. This company also makes cables and wiring insulated with p.t.f.e. Standard Telephones and Cables, Ltd., manufacture a miniature high-frequency co-axial cable for radio and electronic equipment. This cable does not exceed 0.064 in. in overall diameter and is made up of a high-tensile steel wire as the centre conductor, which is copper clad and silver-plated, insulated with polythene, sheathed in a hard drawn copper wire braiding and finally covered with nylon. Another example, seen in Fig. 1, is the

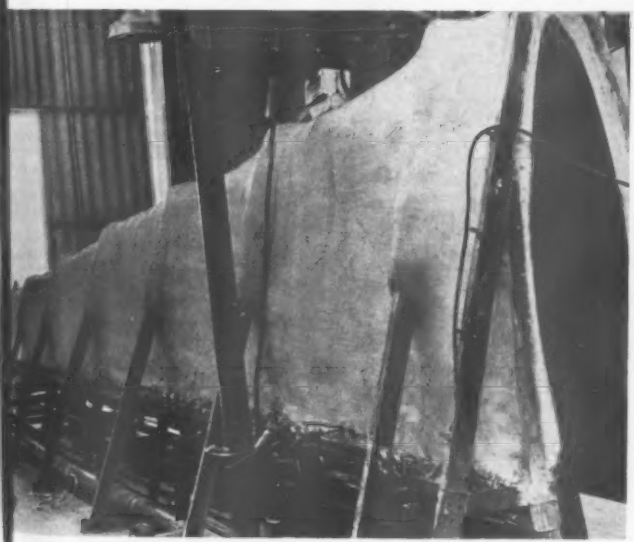


Fig. 6. Main mould for the Miles phenolic-asbestos glider wing.

Nife battery using both polystyrene and polyester-glass in its manufacture.

FURNISHING. With weight-saving as a critical factor it is not surprising that materials with a specific gravity of roughly 1 have been widely employed. Upholstery is in p.v.c., as is panelling and the luggage racks (Figs. 2 and 3). Trims and beading are in high-impact polystyrene. Seat units are in polyester-glass. Trays are in polymethyl methacrylate, as are glasses, whilst cups and saucers and plates are in melamine. The toilet seat is moulded in phenol formaldehyde and the "no-smoking" signs are moulded in polystyrene. An interesting use of p.v.c. is shown in Fig. 4, the shutter for a food cabinet.

OTHER APPLICATIONS. Plastics materials are employed in such items as pressure bottles (Fig. 5) and in many other specialized ways. For example, plastics are used for insulating ducting (expanded polystyrene), for gaskets and seal joints (p.t.f.e. and synthetic rubbers), for canopies (Perspex), for pipe cleats (polythene), for airscrew spinners (polyester-glass), for battery cases (polystyrene), for fire-extinguishing equipment (phenolic), for upholstery (polyurethane), for instrument glasses (Perspex), and for pressure bungs (p.v.c.). And the contribution of plastics by way of the Redux method of bonding metals to metals is of tremendous importance.

This list is indicative rather than comprehensive but, taken with the previous items, will serve to indicate the important part played by plastics in aircraft, and the importance which the plastics industry attaches to the aircraft industry as a customer.

The trend is towards an even greater use of plastics in the above-mentioned areas. This is natural both because of the continuing need to save weight and because of the continual improvement in the performance and properties of plastics. Notwithstanding the impressive inventory above, it does not constitute a major market for the plastics industry as yet, in comparison with the automobile industry, where in the average car some 10 lb. of synthetics are already in use. The big field

Fig. 7. Finishing work on the Miles wing.

for the plastics industry, in terms of tonnage consumption of plastics materials, is in the structure of the airframe itself.

Plastics for Structural Applications

The entry of the United States into the late War created problems of production which even that well-organized country found difficult to solve. A major requirement was a medium for constructing quickly large structures, such as small craft hulls, drop tanks for aircraft, canisters for air drops, tanks for emergency water supplies, etc. A study of the items in what subsequently became a very long list showed that in many cases

Table 1—Thermoplastics
(Materials which soften when heated)

Chemical Name	Typical Trade Name	Typical Applications in Aircraft
Polythene (high density)	Alkathene H.D.	Cable and wire insulation
Polythene (low density)	Alkathene	Cable and wire insulation
Polypropylene (high density)	Moplen	(only recently developed)
Polystyrene	Lustrex	Tableware, galley equipment, interior trim
Polyvinyl Chloride	Geon	Cable and wire insulation, upholstery
Polymethyl Methacrylate	Perspex	Canopy glazing, tableware
Polytetrafluoro-ethylene	Fluon	High duty insulation, gaskets, joint seals
Superpolyamide (nylon)	Maranyl	Gears, cams, cable insulators

Table 2—Thermosetting Plastics
(Materials which are hardened by heat)

Chemical Name	Typical Trade Name	Typical Applications in Aircraft
Phenolic	Bakelite	Electrical equipment, asbestos laminates
Urea	Beetle	Tableware, lavatory equipment
Melamine	Melmex	Tableware
Epoxy	Epikote	Adhesives, resin-glass structures (pressure bottles)
Polyester	Crystic	Resin-glass structures (air-ducting)

Materials and Processes . . . .

a saving in weight was essential and that metals and wood were unsuitable.

Thus there emerged a variant of an old-established technique. The laminating of paper and fabric, employing a bonding medium such as a phenolic resin, had been used for many years in the manufacture of electrical components such as transformer cores. The drawback of this process lay in the necessity for high-pressure high-temperature presses, with expensive steel moulds. The U.S. development involved the use of glass as the reinforcing medium, with a derivative of the paint industry as the bonding medium, a polyester resin yielding a system which required neither heat nor pressure. The glass, in monofilament form, was developed by the Pittsburgh Plate Glass Co.

For many purposes the new materials were excellent. Laminates of considerable strength could be made cheaply, without heat or pressure, on simply constructed moulds made of wood. From that day to this, variations on the theme of glass reinforcement with various resins, mainly polyesters, have constituted the main potential contribution of plastics to aircraft structures. The common method of moulding polyester-glass structures, known as the wet lay-up technique, is to lay glass cloth on the mould, having previously applied a parting agent to secure release, and a gel coat, and then to brush or roll in the resin, which has been catalized chemically to ensure a setting of the resin in a specified time.

To analyse this situation accurately is difficult, for so many claims have been made that the picture is obscure. Basically, whilst perfectly useful items are currently made in polyester-glass, such as commercial-vehicle bodies, small craft, and so on, the material is far from meeting the exacting requirements of the aircraft industry. The modulus of the best commercially available glass cloth at the moment is in the order of 10×10^6 and by the time it has been converted into a laminate this figure is reduced to $2\frac{1}{2} \times 10^6$.

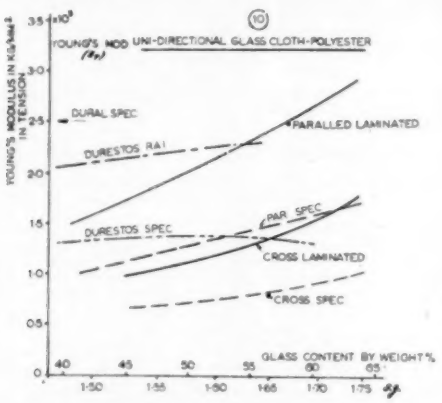


Fig. 9. Comparison of asbestos and glass laminates, and Dural, for Young's modulus.

For aircraft structures, specialists estimate that they need in the finished laminate a modulus of at least 20×10^6. And whilst glass manufacturers are anxious to help, they are faced with development problems which are far from simple in solution and which involve heavy expenditure in so doing.

Again, the polyester range of resins are not ideally suited to the construction of high-performance laminates. They do not wet the glass with 100% efficiency, and they have certain other drawbacks. There are alternative resins, such as those of the epoxy type, and these are capable of giving higher adhesion to the glass.

Finally, the nature of the laminating process itself is such that precise control is difficult, leading to wide variations in physical properties from component to component. This holds good for all hand lay-up techniques and can only be countered by the use of presses or by the employment of a technique such as that developed by Bristol Aircraft, Ltd. Presses, as such, are suitable with metal moulds for small units such as a washing-machine tub, but are theoretically out of the question for very large units.

The Bristol process, which is experimental as yet, may offer hope of more accurate control of properties, but it is not yet clear whether it is suitable for large-size components. Essentially it consists of enclosing glass cloth in closed moulds made of light alloy or wood, and pumping resin through the mould cavities on a circulating system, reducing or eliminating air voids. It is claimed for this process that wetting and consequent adhesion of the resin to the glass is improved, amongst other advantages.

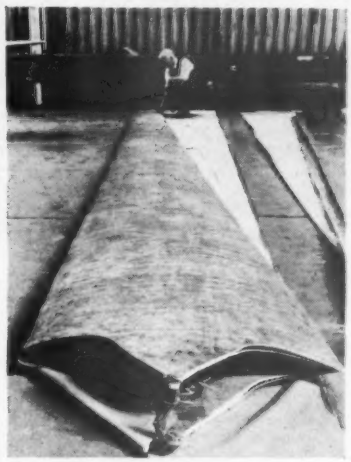


Fig. 8. Completed wing for glider.

It may also be possible to incorporate in this process a high degree of automation, reducing substantially labour costs and enabling finite control of the amount of resin employed in any one component. This latter feature would be a welcome step towards standardization of reinforced plastics' properties.

At the present time there is intensive research being carried on all over the World, which has for its basis the already established data on reinforced plastics. This basic information is extensive, but the forces which have initiated it may be segregated into two distinct fields. For aircraft applications, using this term to cover all airborne applications including rockets, the work has been mainly done either by aircraft companies, such as Bristols, de Havillands, and Miles, or Governmental bodies, such as the Royal Aircraft Establishment at Farnborough, the Naval Ordnance Laboratory, Brookhaven, U.S.A., and similar bodies.

For general applications, such as boats, household items such as sink units, washing-machine tubs and building items such as corrugated-roof lighting and decorative panels, the impetus has come from the laboratories of resin and glass manufacturers. This does not imply that the latter commercial organizations have not co-operated closely with the aircraft and Government concerns. It merely underlines the fact that commercial-risk capital must be predominantly expended in areas of development where returns are most likely to be favourable, and it is obvious that the very high performance demands of the aircraft organization are such as to make this application a doubtful risk. Herein lies the answer to the not infrequent suggestion by certain aircraft companies that more could be done given greater effort by resin and glass manufacturers.

Three examples may be quoted here, two in some detail, to indicate the depth of research that has already taken place in the aircraft field.

The Miles Sailplane Wing

Although development work had been in progress for some long time, it was in May, 1953, that full details were first revealed of the sailplane wing moulded in phenolic resin/asbestos material by F. G. Miles, Ltd. In Fig. 6 can be seen the main mould, constructed of concrete and steel, used to build the wing. Vacuum pressure was used employing the rubber-bag technique, with a complicated heating system capable of curing the phenolic resin in about six hours.

Towards the root of the wing an internal reinforcement was used comprising a paper/resin-bonded honeycomb, visible in Fig. 7 where the wing is being finished. The complete wing, seen in Fig. 8, ready for attachment to the fuselage, was an outstanding development, and it may well be that in the phenolic-asbestos felt materials we have a still largely untapped source for structural plastics.

Whilst the manufacture of the wing was exceedingly costly, it served its purpose adequately without, in its actual application in a sailplane, employing all of the favourable characteristics of the material. Quite apart from load-bearing characteristics, the phenolic-asbestos combination has excellent heat-resistant properties and has been used in rocket structures experimentally.

(*Continued on page* 857)

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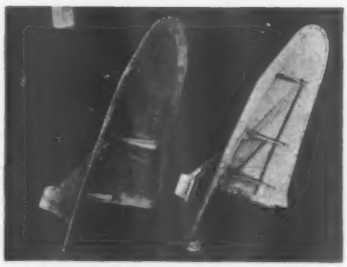

Fig. 10. Sheet metal compared with polyester - glass in wing fuselage fairing.

(*Continued from page* 856)

Finally, in the laboratories of such companies as Turner Brothers Asbestos Co., Ltd., there exist exhaustive technical data on asbestos, much of which remains unused in the practical sense. We also know a great deal about the chemistry of the phenolic reaction, much more than is known about polyesters, and the behaviour of phenolics under stress can be predicted from this basic knowledge.

Fokker's Friendship Airliner

Although not the first major study of reinforced plastics by an aircraft company (Bristols have made exhaustive investigations), the work by Fokker is certainly fascinating. R. J. Schliekelmann, head of the construction research department of Fokker, reviewed progress made by his organization since 1950 in a paper read before the British Plastics Federation's conference on reinforced plastics at Harrogate in May, 1957.

Fokker, in the construction of the Friendship airliner, have made extensive use of reinforced plastics, and Schliekelmann's report is sufficiently detailed for certain conclusions to be drawn. First, only continuous filaments of glass, with high surface finish, are suitable for aircraft. Only in this way can the necessary strength and adhesion between glass and resin be obtained. Secondly, the care with which the glass is made and finished is of paramount importance. Many samples of glass have exhibited physical properties 40% lower than specification, due to careless weaving and chemical treatment.

Schliekelmann also showed the results of comparative tests between polyester-glass, phenolic-asbestos and Duralumin. In Fig. 9 curves are shown for the Young's Modulus (E) for parallel and cross laminations of asbestos and glass. From this it will be seen that the specific modulus for Dural (3.6×10^6 p.s.i.) is substantially superior to the reinforced plastics. It also shows, however, that if glasses with higher E values can be made, this superiority may not be maintained.

On the question of selective cost, Fokker have found that there is a differential, in favour of light metals, of some 10s. per lb., on the assumption that equal weights of metal and plastics are employed. This excess can, however, be partially or completely offset by economies in manufacturing techniques. An example is double-curvature metal parts, requiring either hand forming or expensive tools for drop forming; in reinforced plastics it is possible to produce such parts some 10s. per lb. cheaper. This point is best illustrated in Fig. 10, the wing fuselage fairing of the S.14 jet-trainer. The following table outlines the situation.

Table 3—Wing Fuselage Fairing

	Sheet Metal	Polyester-Glass
Weight	6.6 lb.	6.4 lb.
No. of components	25	2
No. of rivets	581	2
Man hours required to produce batch of 25	100	20

Parts made in reinforced plastics for the Friendship include double-curvature wing-tip structures, fuselage nose, and air ducting (Fig. 11). Some 1,000 lb. of reinforced plastics are employed in an aircraft with an unladen weight of 21,000 lb. Fokker believe that this figure can be substantially increased, provided that successful development work is carried out in the following spheres: improvement of modulus, reduction of specific gravity, improvement of strength of joints, improved heat resistance, lower material prices, and cheaper production methods (e.g., use of pre-impregnated materials).

Radomes

The use of reinforced plastics in radomes is now accepted practice. Plastics were virtually essential in this application, due to the transparency of such materials to radar waves. The development work involved, however, has been tremendous, and many companies have been involved, including Marston Excelsior, Ltd., Thermo-Plastics, Ltd., Microcell, Ltd., and others. The Rees process, of Bristols, has perhaps shown the most outstanding advance in this field. By pumping the resin through a closed mould included air is removed and a high-quality structure is obtained.

It is, perhaps, relevant here, however, to touch upon an aspect of the matter which may profoundly alter the situation in the years to come. An aircraft flying through a rainstorm at 1,500 m.p.h. undergoes an effect not dissimilar to sandblasting. Experience with reinforced plastics radomes indicates, however, that at much lower speeds (500 m.p.h.) their life can be measured in minutes when flying through rain, delamination of the glass and resin occurring.

This experience is only a prelude to even more drastic conditions associated with very-high-speed flight. In short, if the upper limit of aircraft speed is to exceed substantially those operative today, much of the development work to date may be invalidated.

These conditions do not, however, necessarily apply to guided missiles and the like. Rocket launchers have been made in polyester-glass (Microcell, Ltd.), epoxy-glass materials have been used to house rocket-boost motors (Bristol Aircraft, Ltd.) and phenolic-asbestos materials have been employed in various parts in guided missiles.

A great deal of experimental data have been established in this field, the majority of which are unpublished for security reasons. The criteria are so fundamentally different, however, to aircraft structures in the generally accepted meaning of the term that any attempt to make comparisons is useless. An aircraft structure is required to last for a considerable time, whereas a missile may only need to withstand heat and abrasion for seconds or, at most, minutes.

To sum up, it can be said that in the interior of aircraft, furnishing, ducting, galley equipment and insulation, both for noise and electrically, the rôle played by plastics will continue to increase. Each technical advance by the plastics industry will enable a further contribution to be made to safer and more comfortable flight. The plastics industry is well aware of the importance of this, as is evidenced by the many plastics companies who are members of the Society of British Aircraft Constructors.

In the structural field, the work of Fokker and others is encouraging, but tonnage employment of plastics is still very small. It remains to be seen whether the measures advocated by Mr. Schliekelmann can be implemented. To bring this about, one or all of the bodies involved, the aircraft industry, the plastics industry, and the Governmental corpus, will have to invest a considerable sum of money and it may be found preferable, before this happens, to define precisely what the requirements of the aircraft industry are likely to be in 10 or 15 years' time in terms of speed and dimensions.

Only by so doing will it be possible for the plastics industry to make an intelligent assessment of the situation. It may surprise many technologists to know that just as an aeroplane may take years to evolve from the design stage, so do new plastics materials require lengthy development periods. In some cases it may be 20 years before the idea, born in the laboratory, is translated into full-scale production in a chemical factory.

Fig. 11. Luggage rack with integral air ducting, in polyester-glass.

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Metallic Sandwich Construction

In this article MR. A. HOLT, *head of the process development department in the Engineering Research Division of A. V. Roe & Co. Ltd., discusses the history, application and development potential of metallic sandwich construction.*

Fig. 1. The first recorded use of sandwich construction — the Britannia railway bridge across the Menai Straits.

CONSIDERABLE INTEREST has been shown in sandwich methods of construction in recent years—particularly the types used in aircraft. This article sets out to show briefly how this form of construction was first used, its application to aircraft structures and manufacturing methods in current use. It is not possible, however, in the space available, to review the subject exhaustively, and the text has been confined principally to the techniques which are employed at A. V. Roe and Co., Ltd. for corrugation and honeycomb sandwich.

As honeycomb sandwich construction is used by A. V. Roe to a far greater degree than corrugation or any other forms of sandwich construction, readers should bear with the writer if it appears that more attention is devoted to honeycomb techniques. Where necessary, data has been used relating to methods employed by other companies, but waffle-plate, double-Vee corrugation and other types of construction for specific purposes are not discussed.

Sandwich construction had its first recorded use in the building of the Britannia Tubular Bridge (Fig. 1), which carries the railway across the Menai Straits separating North Wales from Anglesey. It is mentioned in letters, which passed between the engineering consultant, William Fairbairn, and his son Thomas Fairbairn in 1845, that experiments were being conducted with relatively thin sheets of wrought iron riveted each side of a wooden filler for use on the parts of the bridge carrying compressive loads.

Robert Stephenson, son of George Stephenson of "Rocket" fame, who built the bridge, subsequently reported to the directors of the then Chester and Holyhead Railway that "cellular" construction had been applied with incredible and unexpected success to the structure of the bridge.

Little was done with sandwich construction until its use was reported in the middle 1920s, when Professor Hill employed balsa-wood cores and wood veneer facings for his Pterodactyl aircraft. It was later used in the same form during World War II on the de Havilland Mosquito.

Progress in the realization of all-metal honeycomb sandwich was delayed for the want of suitable adhesives, and soon after the introduction of Redux phenolic adhesive in 1944 the first metallic honeycomb sandwich panels were constructed. Later, in about 1948, the newly developed Araldite epoxide adhesives were being employed in the experimental manufacture of honeycomb sandwich.

During the early 1950s considerable amounts of light-alloy honeycomb sandwich were in use on American aircraft made by such companies as Glenn Martin, Douglas, Convair and Boeing. But this was almost exclusively used in a secondary structural rôle.

At about this time the improved compression strength/weight ratio and excellent stiffness characteristics of this type of construction, coupled with the increased reliability of the adhesives used for the honeycomb sandwich, were beginning to be appreciated by the designers of very high-performance aircraft. Aircraft which are now in service, and which employ metallic

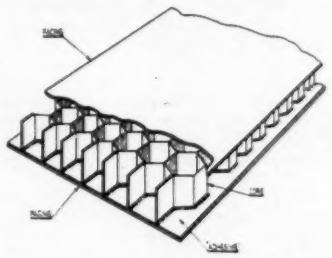

Fig. 3a. Left, the basic honeycomb panel showing its principal components.

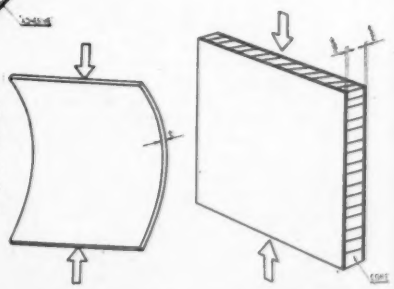

Fig. 3b. Right, a sandwich panel has more than 200 times the compression strength of a single sheet with the same tensile strength—for a 20% increase in weight.

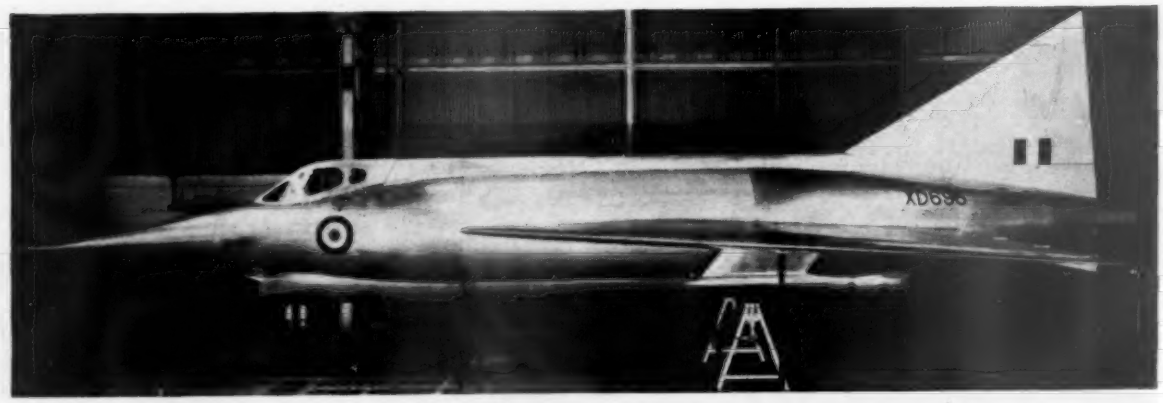

Fig. 2. The mock-up of the Avro 720 research aircraft which was designed to make extensive use of honeycomb sandwich structure.

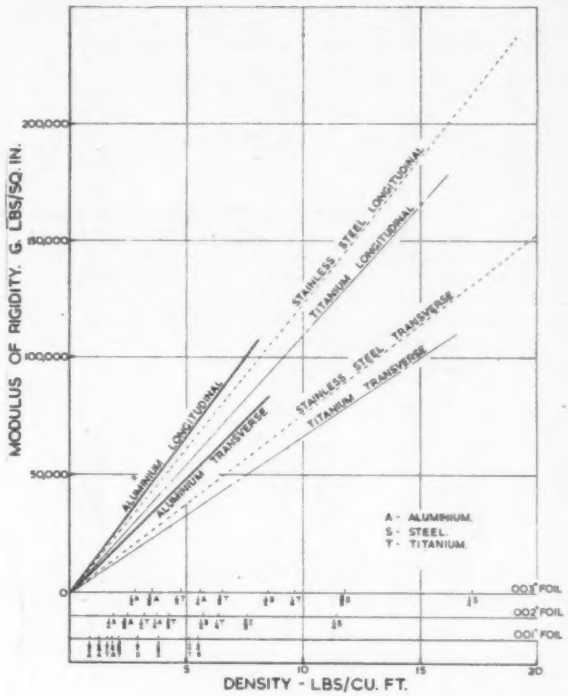

Fig. 4a. Idealized relationship for aluminium H.T.F.1, titanium T.I.150 and stainless steel D.T.D. 571 honeycomb sandwich at room temperature (1-in. core depth). Cell size as indicated.

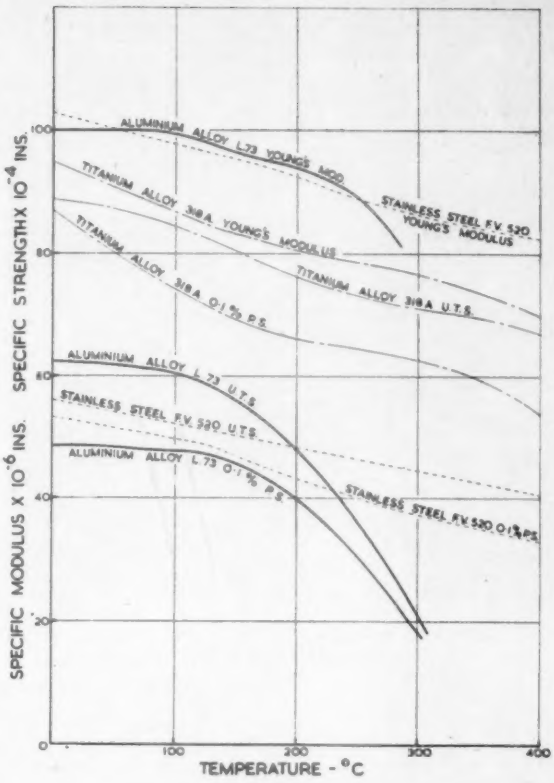

Fig. 4b. The specific mechanical properties of aluminium-alloy L.73, titanium-alloy 318A and stainless steel F.V.520 at elevated temperatures.

sandwich in primary applications, are symbolized by the Handley Page Victor using corrugation sandwich, and the Avro Vulcan using honeycomb sandwich.

An example of an experimental aircraft of which approximately 85% of the total structure was of honeycomb sandwich is shown in Fig. 2. This is the Avro 720, which was not flown after the Ministry of Supply had withdrawn support for it some two years ago. The fuselage of this aircraft consisted of a cylindrical shell of 1-in. thick light-alloy honeycomb sandwich, free from formers and other internal obstructions. Planks of ½-in. thick honeycomb sandwich, spanning from tip to tip, were used for the wing panels. No mass spars were used and flexural stiffness was achieved by the use of light spanwise shear webs.

Theory and Strength Data

To appreciate how stiffness is achieved in a sandwich panel, consider a thin metal sheet placed on one edge; with a compressive load (Fig. 3) the sheet will buckle owing to the lack of stability and bending stiffness. If the sheet is split into two sheets of equal thickness, and these are attached each side of a lightweight metal core capable of transmitting shear, the result at the cost of the extra weight of the core and the adhesive would be a sandwich panel having a very high degree of bending stiffness, and consequent stability under compressive loads.

The fact is that the core provides for effective stabilization of the face plates and is this support has adequate shear stiffness there is no reason why the thinnest sheet (coupled with a core of small cell size) should not develop the full strength of the material in compression.

It is apparent, therefore, that sandwich construction is most efficiently employed in applications which are subjected to compression, flexure or torsion. By selecting the properties which influence these applications a number of graphs and tables have been prepared which in themselves are

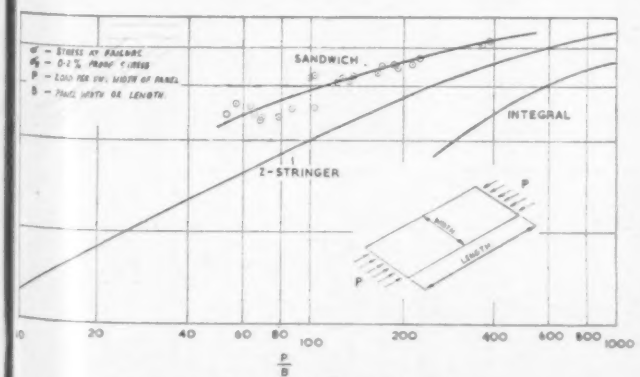

Fig. 4c. Relative efficiencies of stressed skin structure.

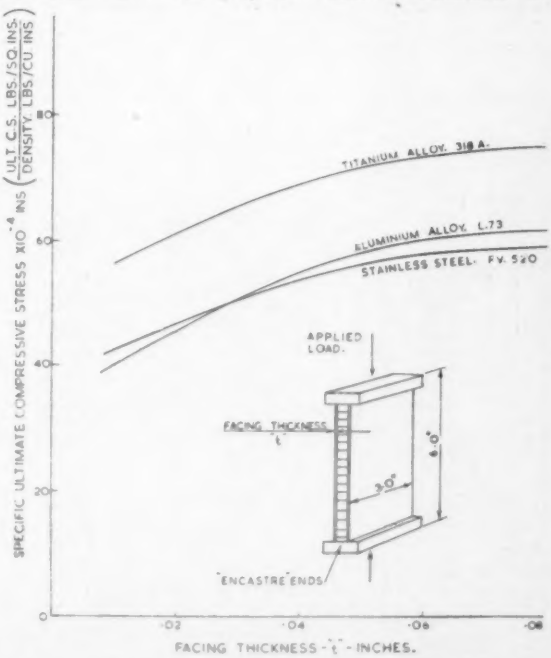

Fig. 4d. Compression tests at room temperature on honeycomb sandwich short-column specimens with the surface material stabilized with a core of ½-in cell size.

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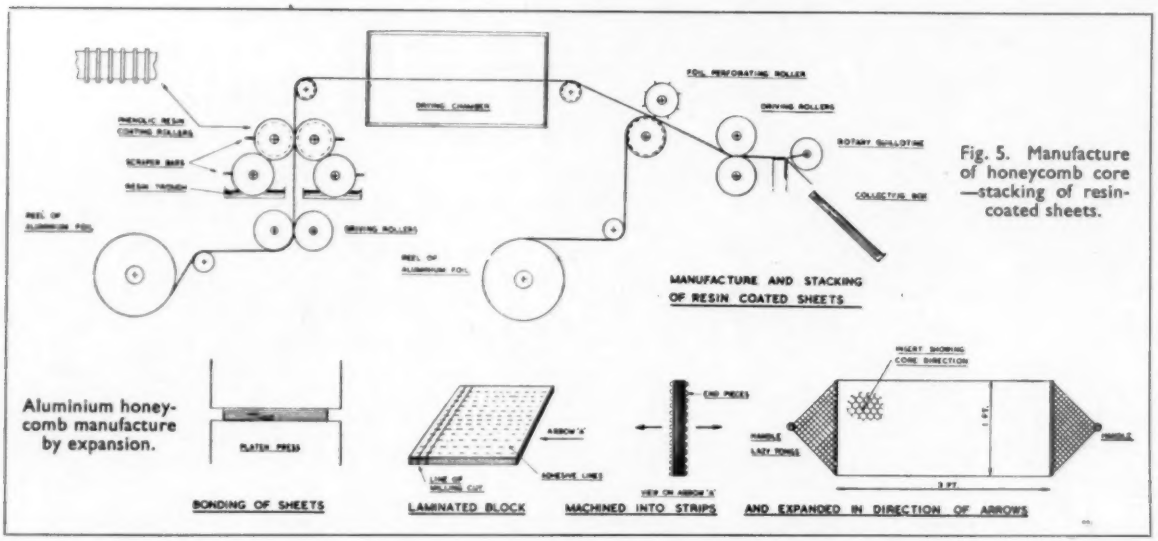

Fig. 5. Manufacture of honeycomb core —stacking of resin-coated sheets.

self-explanatory, and which show the behaviour of sandwich panels in a variety of materials. (See Table 1 and Figs. 4a, 4b, 4c and 4d.) By extrapolation the information from the various graphs may be interpreted to make a reasonable prediction of the performance at high temperature of combinations not specifically listed.

Many advantages stem from the use of sandwich construction, and some of the more important are considered as follows:—

Its use means an immediate saving in weight in certain types of structures, and savings in the order of 15-30% over conventional structures may be achieved with careful design. In this context control surfaces are a good example because, with the introduction of extremely thin skins and the use of honeycomb cores, substantial weight savings are achieved.

On aircraft using sandwich construction the surface finish is considerably improved and the resistance of the structure to deformation increases aerodynamic efficiency as a result of holding laminar-flow conditions to a point that is much further downstream than can be achieved on orthodox skin stringer structures. The resistance to local panting of facings afforded by honeycomb sandwich construction, coupled with the almost complete lack of rivets—each of which can be a formidable stress raiser—makes honeycomb sandwich structures particularly useful for applications subject to fatigue.

Absence of formers and ribs gives increased interior space and improves the design for integral tank and pressurized fuselage construction by the elimination of numerous sources of leakage (assuming honeycomb or all-welded corrugation sandwich). The use of honeycomb sandwich on fuselages of passenger-carrying aircraft will contribute towards the reduction in noise due to the damping effect of the stabilized surfaces as well as the adhesive film.

Experience gained from the full-scale aircraft experiment provided a great deal of information on design features in honeycomb sandwich technique. For example, tip-to-tip panels to avoid chordwise joints; half-lapped method of making spanwise joints; fuselage joints designed to avoid radial drilling; diffusion of concentrated loads with spools and finger inserts; repair methods; and strong points for fitment to bonded panels.

Known and possible applications for metallic sandwich

(*Continued on page* 861)

TABLE 1. COMPARATIVE HONEYCOMB SANDWICH PANEL WEIGHTS

Dimensions, inches			Total weight—facings, core and bonding medium, lb./sq. ft.								
			Aluminium alloy			Stainless steel			Titanium alloy		
Cell size	Foil thickness	Core depth	30G.	20G.	16G.	30G.	20G.	16G.	30G.	20G.	16G.
¼	0.001	½	0.564	1.250	2.065	1.541	3.448	5.718	0.910	1.998	3.293
¼	0.001	1	0.641	1.327	2.142	1.778	3.685	5.955	1.048	2.135	3.430
¼	0.001	2	0.797	1.483	2.298	2.253	4.160	6.430	1.323	2.410	3.705
¼	0.002	½	0.641	1.327	2.172	1.775	3.725	5.975	1.048	2.1355	3.4305
¼	0.002	1	0.796	1.482	2.297	2.250	4.200	6.450	1.324	2.411	3.706
¼	0.002	2	1.106	1.793	2.608	3.200	5.150	7.400	1.874	2.961	4.256
¼	0.003	½	0.718	1.405	2.220	2.012	3.962	6.212	1.185	2.273	3.568
¼	0.003	1	0.951	1.637	2.452	2.725	4.675	6.925	1.598	2.686	3.981
¼	0.003	2	1.416	2.103	2.918	4.150	6.100	8.350	2.423	3.511	4.706
⅜	0.001	½	0.538	1.224	2.039	1.462	3.369	5.639	0.864	1.952	3.247
⅜	0.001	1	0.590	1.276	2.091	1.620	3.527	5.797	0.956	2.044	3.339
⅜	0.001	2	0.693	1.379	2.194	1.936	3.843	6.113	1.140	2.227	3.522
⅜	0.002	½	0.589	1.275	2.090	1.617	3.567	5.817	0.956	2.044	3.339
⅜	0.002	1	0.693	1.378	2.193	1.933	3.883	6.133	1.143	2.227	3.522
⅜	0.002	2	0.898	1.584	2.409	2.567	4.517	6.767	1.507	2.594	3.889
⅜	0.003	½	0.640	1.333	2.023	1.793	3.743	5.993	1.059	2.146	3.441
⅜	0.003	1	0.807	1.494	2.309	2.285	4.235	6.485	1.343	2.430	3.725
⅜	0.003	2	1.127	1.814	2.629	3.271	5.221	7.471	1.916	3.003	4.298
½	0.001	½	0.525	1.211	2.026	1.422	3.329	5.599	0.841	1.929	3.224
½	0.001	1	0.564	1.250	2.065	1.540	3.447	5.717	0.910	1.998	3.293
½	0.001	2	0.641	1.327	2.142	1.778	3.685	5.955	1.048	2.136	3.431
½	0.002	½	0.563	1.249	2.064	1.537	3.487	5.737	0.910	1.997	3.293
½	0.002	1	0.641	1.327	2.142	1.775	3.725	5.975	1.048	2.135	3.431
½	0.002	2	0.796	1.482	2.297	2.250	4.200	6.450	1.324	2.411	3.706
½	0.003	½	0.600	1.287	2.102	1.654	3.604	5.854	0.978	2.065	3.360
½	0.003	1	0.717	1.404	2.129	2.008	3.958	6.208	1.183	2.270	3.565
½	0.003	2	0.952	1.639	2.454	2.717	4.667	6.917	1.594	2.681	3.976

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(*Continued from page* 860)

construction include—for aircraft and missiles—wing panels, control surfaces, air brakes, fuselages, fins, stabilizers, undercarriage and bomb doors, bulkheads, flooring, racking, bunks, tables, doors, trim panels, spar webs, ribs, etc. Other applications include radar aerials, prefabricated house panels, lightweight transportation, elevators, hangar doors, etc.

Manufacturing Techniques

A method of making light-alloy honeycomb sandwich cores is illustrated in Fig. 5. In this, 16-in. foil is fed through rollers which apply continuous stripes of resin on both sides (the stripes on one side are midway between those on the other), following which it is dried and cut into 12-in. lengths which

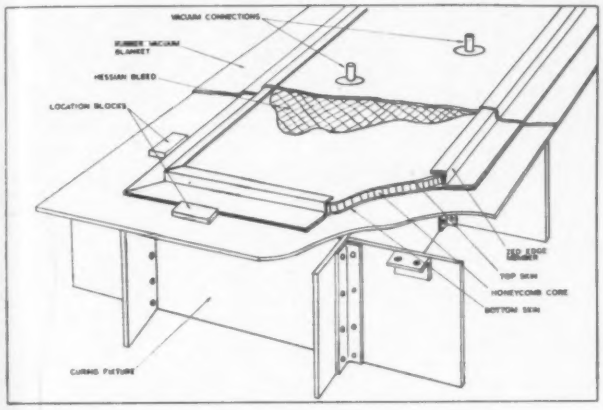


Fig. 7. Typical light-alloy honeycomb curing fixture.

are collected in a tray and interleaved with plain foils of the same size. The resulting stack is heated under pressure to stick the adjacent foils together in the vicinity of the resin stripes. Pieces of the required core depth are then cut from the block at right angles to the resin lines and expanded to form a core with a hexagonal pattern.

The machine which makes this core is capable of producing over 1,200 sq. ft. of core per hour. This core is perforated with fine holes to effect complete vaporization and removal of solvents during subsequent bonding operations. (See Fig. 6.)

For assembly, the cores are coated on their cell edges with Araldite adhesive applied by rollers. The sheet facings are

Fig. 6. A core making machine; this view shows the resin coating rollers.

covered on the inner surface, which makes contact with the core, using a number of thin sprayed coats of Araldite adhesive.

The same treatment is given to edges and internal members, and the components assembled in light-alloy fixtures (illustrated in Fig. 7) are covered with a vacuum blanket. When the air is evacuated from beneath the blanket, which is sealed at the edges, the resulting differential between this and atmospheric pressure forces the components into close contact with the fixture. Whilst held in this state the component is cured at 160° C. for three hours, during which time the items are firmly bonded together. Reductions in the curing-time cycle, as well as processing time, may be achieved with Redux film adhesive at the cost of a slight loss of elevated temperature strength.

Each component is then tested with a specially developed bond tester, which indicates satisfactory or unsatisfactory degrees of bonding, with reference to standard samples of known quality. This equipment is shown in Fig. 8.

A well-tried type of light-alloy corrugation sandwich has been used extensively in the Handley Page Herald, where light-alloy corrugations are resistance spot-welded to light-alloy facings. The inner face of the sandwich, which is also of light alloy, is attached by blind-riveting methods. Quality control of the welding operation is achieved by submitting a given proportion of the welds laid down to radiographic examination.

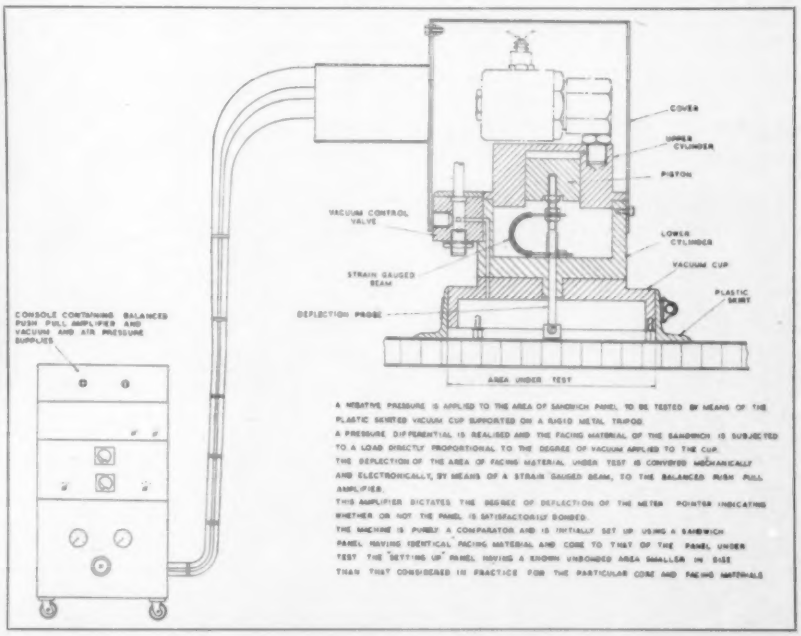

COVER
UPPER CYLINDER
PISTON
VACUUM CONTROL VALVE
LOWER CYLINDER
STRAIN GAUGED BEAM
VACUUM CUP
PLASTIC SKIRT
DEFLECTION PROBE
AREA UNDER TEST
CONSOLE CONTAINING BALANCED PUSH PULL AMPLIFIER AND VACUUM AND AIR PRESSURE SUPPLIES
A NEGATIVE PRESSURE IS APPLIED TO THE AREA OF SANDWICH PANEL TO BE TESTED BY MEANS OF THE PLASTIC SKIRTED VACUUM CUP SUPPORTED ON A RIGID METAL TRIPOD.
A PRESSURE DIFFERENTIAL IS REALISED AND THE FACING MATERIAL OF THE SANDWICH IS SUBJECTED TO A LOAD DIRECTLY PROPORTIONAL TO THE DEGREE OF VACUUM APPLIED TO THE CUP.
THE DEFLECTION OF THE AREA OF FACING MATERIAL UNDER TEST IS CONVEYED MECHANICALLY AND ELECTRONICALLY, BY MEANS OF A STRAIN GAUGED BEAM, TO THE BALANCED PUSH PULL AMPLIFIER.
THIS AMPLIFIER DICTATES THE DEGREE OF DEFLECTION OF THE METER POINTER INDICATING WHETHER OR NOT THE PANEL IS SATISFACTORILY BONDED.
THE MACHINE IS FIRSTLY A COMPARATOR AND IS INITIALLY SET UP USING A SANDWICH PANEL HAVING IDENTICAL FACING MATERIAL AND CORE TO THAT OF THE PANEL UNDER TEST THE "SETTING UP" PANEL HAVING A KNOWN UNBONDED AREA SMALLER IN SIZE THAN THAT CONSIDERED IN PRACTICE FOR THE PARTICULAR CORE AND FACING MATERIALS

Fig. 8. Above, honeycomb bond testing and, right, a diagrammatic arrangement of the Avro bond testing equipment.

Materials and Processes . . . .

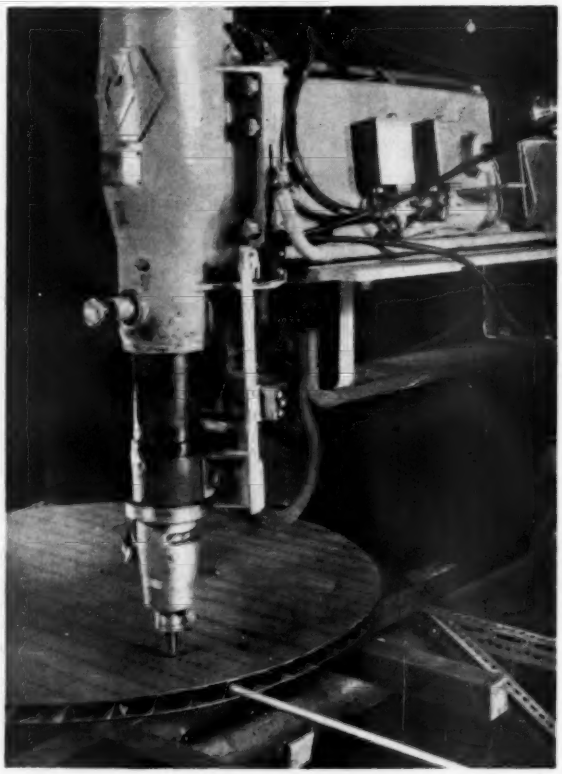


Fig. 9. A typical corrugated sandwich panel being spot-welded, using the patented Avro technique.

This is, of course, additional to the standard shear test control specimens.

To meet higher-temperature requirements, corrugation sandwich has been developed at A. V. Roe which is entirely spot-welded, and uses Firth-Vickers 520 stainless steel. In this technique the corrugation is spot-welded to the outer facings in a conventional manner. To enable the inner skin to be spot-welded to the corrugation-sheet assembly, a variable-thickness "mouse" (intermediate electrode) is used to fill the corrugation space. The retraction and extension cycle for this intermediate electrode is operated in sequence with the main electrodes.

The surface finish achieved by this method is of a very high order, and it is claimed that protrusion and depression of welds on the outer face do not exceed 0.001 in. with respect to the sheet surface. A typical panel is shown in Fig. 9. Sandwich panels of this type give exceptionally high strength in the longitudinal direction up to temperatures as high as 300° C.

Whilst the new high-temperature adhesives, such as Hidux, are likely to extend the use of honeycomb structures into the higher Mach ranges, this is limited to approximately 150° C. Therefore at A. V. Roe a considerable amount of development work has been carried out on stainless-steel honeycomb structures, a few examples of which are illustrated in Figs. 10a, 10b and 10c. These structures are capable of operating at temperatures of 300° C. (Mach 3 approximately) with very slight reductions in properties compared with those at room temperature.

In this technique facings of high-strength, heat-treated, stainless-steel sheet (designated Firth-Vickers 520 steel) are used in conjunction with honeycomb cores made from 18-8 austenitic stainless-steel foils. The attachment of core to facings and edge members is achieved by the use of a copper-silver brazing alloy and special fluxes which do not leave any residues.

All the steel honeycomb components shown in the illustrations have been made in one brazing operation, and it is thought that these are some of the largest in existence at the present time.

Whilst specific strength and stiffness of the steel honeycomb at elevated temperatures is considerable, superior performance may be achieved with titanium alloys for the lower temperatures, and Nimonic 100 for the higher-temperature ranges. To date no work has been done by A. V. Roe on the manufacture of Nimonic 100 sandwich panels, but a limited amount of development has been carried out with titanium-alloy honeycomb and corrugated sandwich panels, which hold out interesting possibilities.

Looking further into the future, even more exotic combinations may be possible. These may well centre on such materials as beryllium and molybdenum/titanium alloys, providing such materials become available in large-sized sheets at an economic price.

Potentialities

In addition to the structural applications already outlined, a big future for sandwich construction, particularly honeycomb sandwich, is in the field where structures are subject to high-intensity jet noise, and considerable success has already been enjoyed in this connection.

In view of the high degree of dimensional accuracy coupled with great stiffness, spectacular improvements have been achieved in the performance of radar aerials, and as the size increases a large field is opened up for exploitation.

Stainless-steel honeycomb offers possibilities to the designers of missiles in view of the readiness with which it can be made into cylindrical shapes, its high specific strength and stiffness, its ability to be used as a pressure vessel and its resistance to elevated temperatures. Another field in which stainless-steel honeycomb might be used is in the fireproof shrouding round jet engines. (Samples have been made of ¼-in. thick sandwich weighing 0.56 lb. per sq. ft., which is equivalent in weight to a single sheet of 29 s.w.g. stainless steel.)

From the foregoing notes it will be obvious that we at A. V. Roe are anxious to use sandwich construction, and are preparing to meet the many challenges this interesting branch of engineering is going to present in the future. And, finally, it should be noted that the processes described in this article relating to light-alloy and steel honeycomb sandwich, as well as those for the steel corrugation sandwich, are the subject of British and foreign patent applications.

Fig. 10. Left (a), a large steel honeycomb cylinder 6½ ft. in diameter and 7 ft. 6 in. long. Above (b), a curved panel in steel honeycomb sandwich 8 ft. by 4 ft. Right (c), a section of a stainless steel honeycomb sandwich leading-edge.

Materials and Processes . . . .

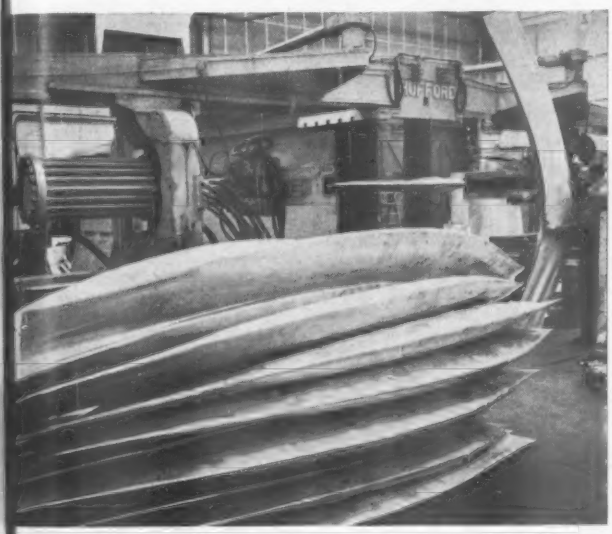
New Techniques and Processes

By David W. H. Godfrey, A.F.R.Ae.S., M.I.A.S.

IN RECENT YEARS the traditional methods of airframe fabrication have been supplemented by new techniques. These have either made possible more efficient structures, by the use of new materials and new ways of manipulating older materials, or else have extended the use of existing practice.

Discounting light aircraft of wooden construction, the main interest is in current methods of fabrication of metal structure and the means of joining or fixing one component to another. There are two basic aspects to be considered—techniques adopted in the cause of load-carrying efficiency of orthodox metal structure, and special techniques required for the use of new materials.

Static load-carrying capacity of an airframe is no longer the only criterion for design, and considerations of fatigue life are now most important. Two terms which have been much used are "safe life" and "fail-safe," the former denoting an airframe based upon an estimated fatigue life and the latter covering the provision of alternative load-paths and crack-stoppers. These concepts have had major effects on the methods of fabrication used.



An example of stretch-forming-wing tips being produced with the aid of a Hufford machine at Armstrong Whitworths.

Orthodox practice involving the use of bolts and rivets to secure one structural component to another has been supplemented by metal-to-metal bonding (Redux) and by spot-welding. Sheet material and extrusions are now often stretch-formed to obtain better results than would be obtained by stampings or pressings. For large aircraft, integral machining has been adopted where it is advantageous to have large panels with integral stiffeners rather than separate stringers and ribs.

Another means of achieving this type of one-piece panel is contour etching (or chemical milling) where the unwanted metal is eaten away by chemical action. For certain applications honeycomb-core structure is used.

There are several well-known methods of riveting and various types of rivets in common use. Current practice is to countersink skin for rivets by one of two methods. Either the skin is spin-dimpled or else a doubler plate is bonded on the inside face of the skin to give enough "meat" behind a countersinking cut in the skin. Rivet heads may then be machined flush with the skin in the interests of drag reduction.

In recent years there has been a greatly increased use of tight-tolerance bolting of joints—particularly at such locations as wing roots—for the purpose of obtaining a long fatigue life. A good example of this is the de Havilland Comet 4 which has a wing root joint life 50 times as great as that of the Comet 1. In this case, the minimum clearance on diameter was reduced to 0.0002 in., a special anti-fretting compound was used and the tolerance on parallelism through steel and aluminium structure was held to within 0.0005 in.

In cases where a bolted joint is required, but the joint does not have to be readily unfastened, Hi-Shear bolts have found increasing use. These have the advantage of taking the place of a normal bolt, but have a soft "nut" which is deformed like a rivet tail to lock the bolt in place.

Metal Bonding

Bonding is perhaps the biggest recent advance in basic airframe fabrication. Used at first for wood-to-wood and metal-to-wood joining, it is now widely employed for metal-to-metal attachment of primary structure.

Aero Research have developed a range of bonding techniques using their Redux adhesives, and these are now in use in a number of countries throughout the World. Simply put, bonding is an elegant method of glueing involving the use of thermosetting and thermoplastic resins applied to the parts to be joined, which are then heated under pressure until the curing operation is complete.

There are various techniques used for the bonding process, each company having its preferences according to its experience and requirements; most commonly either hydraulic presses or autoclaves are employed. In either case, heating is usually by means of steam or electricity (though SAAB in Sweden use a high-pressure water system).

In autoclave bonding the pressure is provided by vacuum on the bonding jig and by compressed air. Where low pressures only are necessary, and this particularly applies to honeycomb sandwich bonding, vacuum pressure only may be sufficient, the components being placed on a heated table and covered with a rubber blanket to which a vacuum pump is connected. Ordinary ovens may also be used for this type of bonding. Although this simpler apparatus may be used in certain types of honeycomb sandwich bonding, presses and autoclaves already installed by most aircraft companies are also very suitable.

The virtues of bonding are several. Far greater stiffness and fatigue life for a given weight are achieved than with riveted attachment of stringers to panels, because the whole area of the stringer flanges is in intimate contact with the panels. This prevents inter-rivet buckling. Other advantages are reduced

Integral machining—routing a thick slab with the contour controlled by overhead template.

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cost of production and design, simpler assemblies and increased smoothness of outer contours.

Where it is desired to have integral fuel tanks in the wings of an aeroplane, the use of bonding avoids the problem of sealing thousands of rivet holes. Similarly, for a pressurized fuselage, the sealing problem is minimized. Load-diffusion around cut-outs and other discontinuities of structure are conveniently accomplished by bonding-on doubler plates to stiffen the open edges. A "wash-out" of load can conveniently be made by using underlapping bonded laminations. At the transport joints of wing sections, loads from joint-face ribs are diffused to spanwise stringers through "finger plates."

As Fokkers have shown, it is possible to avoid the use of extruded sections by employing spar booms laminated by bonding simple folded sections of light alloy. These can be laminations simply reduced in size and number towards the tips. By the use of extensive Redux bonding throughout the airframe of the Friendship the Dutch company has avoided the use of a great number of machine tools (see THE AEROPLANE, February 14).

An interesting application of Redux bonding has recently been made in Germany. Here the complete outer wing of the Blume Bl.502 aircraft was bonded in an oven in one curing operation, the special assembly jig being also the bonding jig.

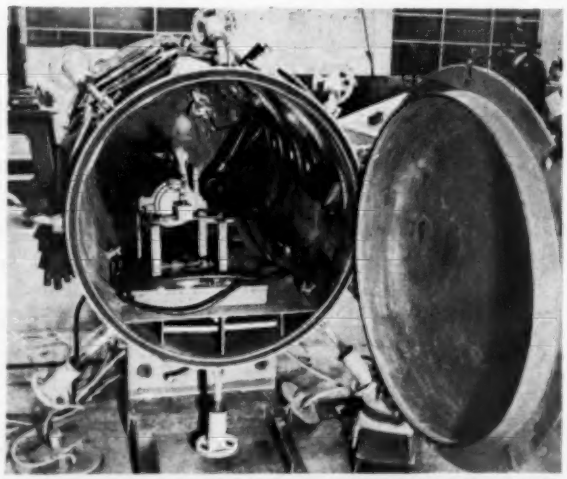
Resistance Welding

For various reasons resistance welding has always been regarded with some reserve for airframe primary structure. However, there are a number of modern aeroplanes which have spot-welded primary structure—the Caravelle, Cougar, Herald, Scorpion, Stratotanker and Victor.

The advances made in this technique have been the result of rigid process control. Success or failure can be assessed by statistical methods of quality control and sampling inspection. For light-alloy spot welding improved radiographic techniques provide the final check. Very high-speed aircraft may be one of the best applications of welding because kinetic heating rules out the use of adhesives, whereas the weld is no more affected by environment than the parent metal.

As with bonding, spot welding is largely used for the attachment of stiffening stringers to sheet. Drawn-section stiffeners are commonly used, although extruded or machined stiffeners are also used where fairly large differences of thickness are involved. Other applications of spot and seam welding are for fuel tanks, structure sealing, thermal de-icing ducts, air intake ducts and so on.

Flash-butt welding of steels and low-grade aluminium alloys is an accepted practice for certain applications such as the joining of fork-ends to tubes in push-pull control rod circuits and other mechanisms. Considerable weight is saved over riveting or taper-pinning because the plug end of the fitting need only sit in the tube a very small amount.



A cabinet for welding titanium in an inert gas; the interior of this de Havilland cabinet can be seen in the upper photograph.

Stretch Forming

The forming of aircraft skin panels by drawing over a pattern has found increasingly wide adoption in recent years and there can be few people in the aircraft industry who do not know what a Hufford machine looks like. The method is now well established and is a very useful means of producing skin panels where the curvature, although not severe, may assume fairly complicated forms not corresponding to conventional geometric shapes.

Stretch forming is often used to shape parts in one piece which would otherwise be made up from several pieces of drop-hammer work. For instance, a wing tip originally made in halves from soft aluminium on a drop-hammer can be stretch-formed on a Hufford machine in one piece of aluminium alloy. The result is cheaper and quicker to produce, and is more satisfactory from the viewpoints of handling before assembly and strength. One-piece construction also saves the weight of a butt-strap joint necessary with some two-piece components.

An example of stretch-formed extrusions is on the Armstrong Whitworth A.W.650 main fuselage frames. For this, a special Jabroc tool was made and the results have been highly satisfactory.

Drop-hammer Developments

A recent advance in drop-hammer technique is the use of super-annealed material, the grain size of which is controlled through all stages of manufacture from the billet onward. Great success has been achieved with fabrication of this material, largely because it is possible to reduce the amount of heat-treatment needed during the forming process.

Super-annealing is obtained by very slow cooling from the annealing temperature, with resultant ease of forming. For example, on one door pan material in the ordinary annealed state required five heat-treatments whereas super-annealed material required but two treatments. Also, the scrap was reduced from a fairly high rate to almost nothing.

An associated development of drop-hammer work is the use of plastics-faced tools, the tool face being coated with epoxy resin of the Araldite type. Until recently, lead and zinc tools were used which required many hours of fettling and, even then, dangerously thinned vertical walls often occurred in early pressings.

The method of facing, as made by de Havillands, is to support the pattern about ½ in. from the face of the rough-cast die, to seal the edges with sponge rubber and marking tape and pour epoxy resin mixed with slate filler into the cavity thus produced. After coating with a suitable parting agent, the rough-cast punch is similarly faced by setting ½ in. away from the die.

By varying the percentage of thiokol in the resin, the punch is made relatively flexible compared with the die. The flexible punch allows gauge thicknesses up to 20-22 s.w.g. to be ignored. More exact pressings are produced than with the older method, there is less scoring of the component during fabrication and damage marks in the die face disappear with use.

Integral Machining

Production of large sections of airframe structure in one piece with integral stiffeners is a relatively recent development and its wider adoption in this country has been held back to a certain extent by lack of suitable machine tools. The object of using this type of construction is twofold—a smoother outer surface to wings and tail unit is obtained because it is

(*Continued on page* 865)

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(*Continued from page* 864)

possible to work back from the desired contour; and the use of integral stiffeners both saves weight and improves structural efficiency because of the increased stiffness.

The fewer the different parts which comprise an assembly, the lighter it is for a given strength. The idea of integral construction is therefore attractive and in theory it would be an advantage to start with a large slab of metal and proceed to cut away the unwanted material. This can only be done, of course, where sufficiently large billets of raw material are available.

An obvious requirement was for high-powered machine tool cutters so that the large amount of metal being scooped from the solid could be removed as soon as possible to avoid unduly lengthy machining operations. Also, copying devices had to be developed for accurate cutting of the required contours and special attention was needed for the problem of the disposal of metal swarf which would otherwise bury the machine tool in its own chips.

Other problems to be solved were the means of holding the billet on the bed of the machine while cutting (such as the use of a vacuum table for light alloy and a magnetic bed for ferrous material) and the all-important issue of straightening the machined components.

This last-named matter is essential because the machining operation is rarely symmetrical and produces considerable stresses in the component, even after intermediate heat treatment. There are several methods which have been used to alleviate the distortions produced by machining—the use of pre-stretched stock, straightening in presses after working, machining before heat treatment, several intermediate heat treatments, final surface machining to true-up the component after working, use of a stamping device on a bed of steel balls, the use of forged stock and so on.

A typical method is to use light-alloy stock which has been stretched a minimum of 1½% in slab form, making a roughing cut followed by annealing to adjust the material structure and main machining in the annealed condition. After a final heat treatment, a last trimming cut of not more than $\frac{1}{16}$ in. is made—no more, or fatigue strength is reduced because the whole of the compression surface produced by the heat treatment has been machined away.

No hard and fast rules can be made for the machining technique adopted, each company making appropriate allowances according to its experience of those surfaces likely to distort. In the case of light alloy it is important that no adjustment in terms of stretching is made when the material is fully aged or else cracks are induced.

The use of forged stock in high-strength aluminium alloy has been limited in this country by the lack of sufficiently large forging presses for anything like reasonable areas of integral construction. Forging to close tolerances is apparently attractive, but even on relatively small sections this is governed by the pitch of stiffening ribs and there has been little success so far.

Cutting from the slab is therefore the method most widely used at present for integrated aircraft structure and suitable machine tools have been developed by individual aircraft companies (Blackburn, Fairey, Armstrong Whitworth, Boulton Paul, Vickers) in addition to the traditional manufacturers of such equipment. Skin millers have been developed capable of cutting with very great accuracy the outside profile of a wing aerofoil. It is quite possible that the use of computer-controlled machine tools may be extended to cover this type of work and may, in some cases, be almost the only way of obtaining certain intricate contours.

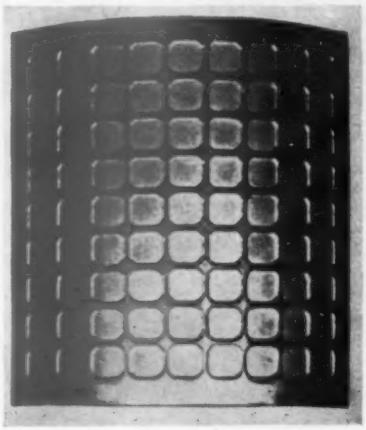
Contour Etching

Largely as a result of the considerable difficulties of distortion after integral machining, the process of chemical milling or contour etching has been developed. In this, unwanted metal is removed by chemical erosion with masking to protect the areas to be retained.

For light alloy the corrosive liquid used is caustic soda and for steel an acid is required. Immersion of a suitably masked slab of metal in the liquid is carefully controlled to produce the required hollows in the finished component.

The process has been successfully applied to relatively thin panels where machining would be a tricky and delicate operation. For thick panels, there is some limitation on its use because of the large amount of bubbles which occurs in the corners and restricts the effectiveness. At present, the maximum depth of etching possible is more than an inch.

Advantages of contour etching are that it is much cheaper than the use of large machine tools; its use does not cause additional stresses as a result of the action of the tool; the component shape can be the final shape required; a large number of detail tools are eliminated; there is a weight saving;



A good example of chemical contour etching as produced in France.

and, because there is only one component, there is a considerable reduction in the amount of accompanying paperwork. One of the main points with contour etching, however, is that there is no problem with double-curvature components such as a nacelle tank skin.

The process is of four basic stages—pre-treatment and cleansing of material; application of masking; etching; and post-treatment (neutralizing and cleansing).

An example of the technique as practised in America is the new plant at the Pomona factory of Convair. The masking and curing installation is in the form of a continuous overhead conveyor system. Parts suspended from the conveyor are automatically dipped in a bath of masking compound. The mask is air-dried while the parts are being conveyed to a heated curing tunnel. Each part makes four circuits of the conveyor system to build up a masking coat sufficient to withstand the etching process.

After final drying, masking is stripped away from the areas to be etched. Precise trimming is important because accuracy of the trimmed mask controls accuracy of the etched area. The part is next immersed in the etch solution for a predetermined time, depending upon the amount of metal to be removed. After etching, the part is rinsed and brightened in a mild etching solution to remove any surface discoloration.

Contour etching is particularly useful for curved components, such as the inside surface of a wing leading edge, and for producing skin panels of varied thickness.

Titanium Fabrication

Truly a "jet-age" material, titanium alloys present special problems of fabrication, particularly in welding and stress-relief. Titanium must be welded in an inert gas, usually argon or helium, and a special cabinet has to be devised whereby an operative can perform the welding operation from outside.

Cabinets of this sort have been developed by Vickers, Bramahs and de Havillands. Assemblies to be welded are loaded into fixtures and sealed inside the cabinet, air is evacuated and replaced by argon gas. The welder puts his arms into sealed rubber gauntlets attached at the elbows to manholes in the cabinet and views the welding operation through portholes.

Design of fixtures for welding in this cabinet requires special attention because the titanium parts must be held butted together with a maximum gap of 0.020 in. The welder must be able to move the welding fixture to set it at all the various attitudes he needs and it must therefore not be too heavy and be capable of standing at various attitudes. Sharp edges must be avoided because, if he punctures the rubber gloves, the leakage of air into the chamber will cause embrittlement of the weld and the part will be scrapped.

All heavily formed titanium parts have to be stress-relieved at 500° C. for 10 minutes or for half an hour if held in a fixture during this treatment and generally it must be firmly held or it will distort severely. Until recently, expensive heavy steel fixtures were used, but a method of casting in refractory concrete has now been developed. This technique is to cast a mixture of refractory cement and firebrick on to a fully adjusted component, thereby producing a matching mould with exact allowance for the gauge of the material. The weight of the fixture prevents the component from distorting, corrects and sets it to the exact shape required. Titanium sections can be stretch formed although it is a slow process and heated tools must be used.

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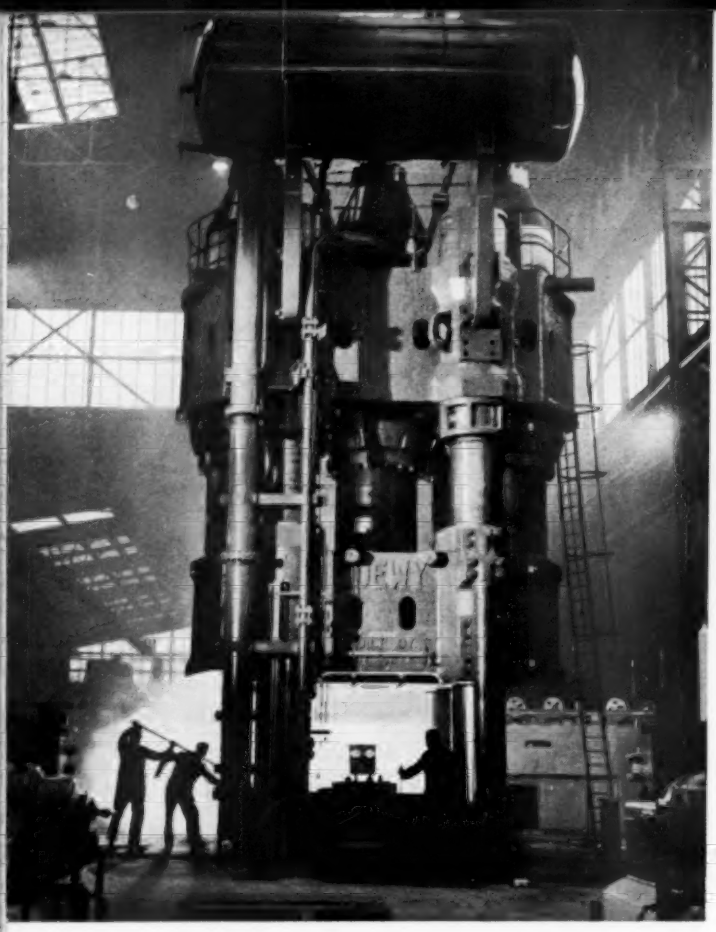
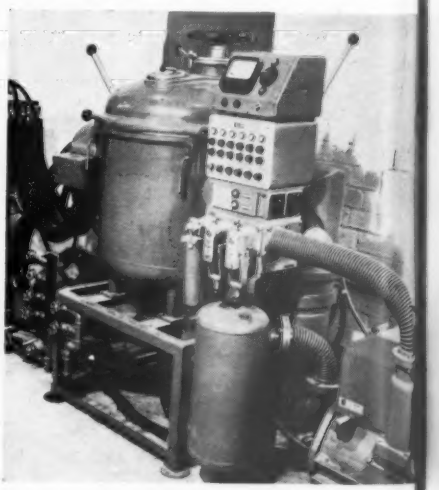
Trends in Ba



Left, largest of its type in Britain is the 12,000-ton forging press of High Duty Alloys, Ltd.



Right, this high-frequency induction furnace is used for the vacuum melting of alloy steels by William Jessop and Sons, Ltd., of Sheffield.

THE STORY of the basic fabrication of aircraft materials is closely linked with the development of new materials. New alloys, based on steel, aluminium, magnesium and nickel, have been developed over the years to meet the needs of aircraft and missiles; new metals such as titanium and zirconium have also come upon the scene. These alloys have in many cases a strength and toughness far ahead of traditional materials; these very properties make them difficult to work and demand the introduction of new basic fabrication techniques.

Probably the two most important developments recently have been the production of stretcher levelled plate for integral construction and the use of vacuum-melted and cast steels. But standard techniques are constantly being refined and applied to new materials; and although there have been no striking new advances, steady progress has been made in many basic-fabrication techniques during the past few years.

Typical is the progress which has been made with aluminium-alloy sheet. This has been reflected in successive D.T.D. specifications. A wider range of sheet widths has been produced and sheet tolerances have become closer, as well as becoming bilateral and applying to the whole of the sheet. The evolution of the continuous-casting process has enabled larger ingots of even quality to be produced, permitting the production of wider and thicker plate.

In the same way, forging techniques have been improved and progress made towards zero-draft-angle forgings. If there is no flash at the edges of a forging, there is no cross-grain material flow and mechanical properties are greatly improved. Moreover, the amount of subsequent machining is much reduced. High Duty Alloys, Ltd., is a leading company in this field and its 12,000-ton press is the largest of its kind in this country.

Extrusion techniques have been improved and are now applied to titanium, steel and the Nimonic alloys. Use is being made of the French Sejournet process, in which molten glass is used to lubricate the flow of metal through the dies.

One of the main developments in casting is the use of vacuum-melted metal to produce high-strength castings. Another technique is centrifugal casting for engine rings; this ensures that the pure high-density metal is on the outside of the ring and that any light inclusions are confined to the inner surface.

Precision-casting techniques in use include the lost-wax and frozen-mercury processes. The solid-mercury technique involves the use of a pattern of frozen mercury; it is expensive but one which produces high-precision castings suitable for such items as radar waveguides and hollow turbine blades with passages for cooling air.

The most suitable technique in this country for the production of integral skin-stringer panels is to machine them from solid slabs of aluminium alloy. Such slabs must be stress-relieved by stretching after heat treatment; if this is not done distortion results when the internal stresses are unevenly relieved during machining.

Large stress-relieved aluminium alloy slabs are now produced by the Northern Aluminium Co., Ltd., at its Rogerstone works in Monmouthshire. They are also available in somewhat smaller sizes from James Booth and Co., Ltd., of Birmingham; this company can supply stretch-levelled plates up to 35 ft. long by 35 in. wide and with a maximum cross-sectional area of 62 sq. in.

Size limitations of Noral stretch-levelled slabs produced at Rogerstone are: length, 50 ft.; width, 7 ft.; thickness, ranging between ½ in. and 6 in.; cross-sectional area 200 sq. in.; and weight 4,300 lb. The casting of ingots for rolling into plate imposes another limitation and at present it is not possible to combine the maximum of all three dimensions in one plate.

The plate stretcher installed at Rogerstone has a rated pull of 4,000 tons and can apply a controlled stretch to light-alloy plate up to 50 ft. long by 10 ft. wide and 6 in. thick, and with a maximum cross-sectional area of 200 sq. in. There is provision for increasing the pull to 6,000 tons should this be found necessary. The stretcher was designed and built by the Loewy Engineering Co., Ltd., of Bournemouth.

Internal stresses are set up in aluminium-alloy plates as the result of quenching after solution heat treatment. The most effective method of relieving these stresses is by controlled stretching of the plate so that there is at least 1½% permanent strain. On the Loewy stretcher the degree of stretch can be pre-set to 1, 1½, 2, 2½, 3, 4 or 5% and the operation will automatically stop as soon as the pre-set value is reached. An alternative technique is for the plate to be stretched until a predetermined stress has been reached.

A new heat-treatment furnace has also been installed at Rogerstone for handling large aluminium-alloy plate. It can be used for solution treatment, artificial ageing and annealing. Its capacity is nearly 20 tons of plate for ageing at temperatures up to 200°C., without quenching; 10 tons for solution heat treatment up to 550° C. with a slow quench; and 5 tons for solution treatment up to 550° C., with a high-speed quench. It can handle plate up to 55 ft. long by 10 ft. wide and 6 in. thick.

Basic Fabrication

By J. R. Cownie, B.Sc. [Eng.], Grad. R.Ae.S.

Also at Rogerstone are 10 extrusion presses, including an 8,000-ton one which is said to be the most powerful at work in Britain. Many of the large light-alloy wing-spar extrusions used on British aircraft are produced on this press.

Vacuum-melting techniques are essential in the production of titanium, as the liquid metal is highly reactive and rapidly forms a solidifying mass of titanium oxide if it is melted in air. Even if only small quantities of air are present enough oxygen may be dissolved to make the metal hard and brittle. It has thus been essential to develop vacuum-melting techniques for titanium and other metals, such as zirconium, which react with air.

Recently vacuum melting has been applied with advantage in the production of special steels—a leader in this field is William Jessop and Sons, Ltd., of Sheffield. The main advantage of this technique is the freedom from non-metallic inclusions and impurities in alloys produced by it. This greatly improves the fatigue properties of highly-stressed components made from vacuum-melted steels; it also improves the ductility, particularly in directions at right angles to the grain flow.

Typical examples are given by the effects of vacuum melting on a creep-resisting steel disc and a high-speed steel for ball bearings. Longitudinal ductility of the forged disc was increased from 15 to 20% and its transverse ductility went up by three times. The largest non-metallic inclusion in this forging was found to be only 0.003 in. long. The fatigue strength of the ball bearing steel was increased from ±40 to ±43 tons/sq. in. for five million reversals.

Other advantages of this new technique are that gas content of the steel can be controlled and its chemical composition decided more exactly. It not only offers improvements in the mechanical properties of existing alloys, but also shows the prospect of producing new super alloys which cannot be melted by conventional methods.

Many applications can be expected for vacuum-melted steels. Their qualities offer immediate improvements for ball races and bearings, compressor and turbine blades and discs, high-grade polished sheet and tool and die applications where perfect finish is required. Vacuum-cast sticks have been used as raw material for lost-wax and similar casting processes.

Two methods are at present used by Jessops; they are the consumable-electrode arc-melting process and the high-frequency induction-melting process. With the first, air-melted material is used as an electrode and remelted in a vacuum; ingots up to two tons in weight can be produced. The induction-melting process is suitable for alloys of which an air-melted electrode cannot be produced; a melting installation is on order which will make possible production of 600-lb. ingots in this way. For titanium a double-melting technique is used in which the ingot from the first melting acts as the consumable electrode for the second melting; ingots with a diameter up to 20 in. can be produced.

One of the leading companies in the development of forging techniques to meet aircraft needs is High Duty Alloys, Ltd., whose Forging Division is at Redditch. Its development of precision forgings for aircraft has followed from its work on precision-forged turbine and compressor blades for jet engines.

Much progress has been made in the production of precision-forged and draftless components to very close tolerances. Large aluminium-alloy forgings of thick section have been produced for undercarriages for a considerable time. These forgings were invariably machined all over, and surface finish and accuracy of the forgings were not of prime importance.

More recently the trend towards integral construction has produced a demand for large airframe-structure forgings. These have imposed stringent new requirements of surface quality and dimensional accuracy. There is a demand for the machining of such forgings to be reduced to the minimum.

Press Forging

New developments in press forging and heat treatment techniques have been necessary to produce these airframe-structure forgings. High-quality ingots produced by semi-continuous casting have been used for such press-forged components.

Die forging is used to produce shapes as close as possible to those required and also to improve the mechanical properties of the forgings. Progress in the production of low-tolerance aircraft components has been complicated by the simultaneous development in component design. With fittings becoming larger and more complex the task of the forging specialist has become more difficult.

High standards of surface smoothness and freedom from small defects can only be achieved by careful preparation before pressing and experienced rectification during this process. Dimensional accuracy begins with the die and here, despite use of the latest machines, the skill of the die-sinker plays an important part.

Die wear will affect accuracy and must be taken into account in die production. Thin webs can only be produced by very high forging pressures; the dies must be able to withstand these pressures and resist the flow of hot metal without premature collapse. Metal flow is helped by heating the dies, but present die steels limit the operating temperature to about 400° C. If suitable materials were available this temperature could profitably be raised to 450-500° C.

The temperature of the die and forging must be very accurately controlled. The significant effect of temperature fluctuations is indicated by the fact that a 15-ft. aluminium-alloy spar alters in length by 0.14 in. per 100° C.

Distortion during heat treatment or machining can ruin a

Large aluminium-alloy plates are stress-relieved by stretching them on the 4,000-ton stretcher installed at the Rogerstone works of the Northern Aluminium Co., Ltd. Another view of this machine is on page 872.

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perfect forging. Heat treatment sets up an internal stress system in a forging. For this reason forgings should be heat treated wherever possible in the fully-machined state and quenched in boiling water. If insufficient dimensional control is obtained in this way, machining after heat treatment should be carried out symmetrically.

A stress-relieving technique which has been applied to simple cylindrical forgings is to give them a controlled cold upset on a large hydraulic forging press. This gives an effect similar to the stress relief by stretching used for extrusions and plates.

Titanium Production

Latest development in the basic fabrication of titanium is the opening of the I.C.I. rolling plant for rod and sheet production at Waunarlwydd, near Swansea. Raw titanium for this plant is extracted at the I.C.I. Wilton plant and is sent to Waunarlwydd as bar, strip and machined slabs via the company's melting plant at Witton, Birmingham. Equipment here makes possible the production of 4,200-lb. ingots of titanium.

Capacity of the Waunarlwydd plant is 1,500 tons per annum of rolled bar and rod in diameters ranging from 5 in. to 0.25 in. and 300 tons of rolled sheet in commercially-pure titanium or lesser quantities if alloy as well as commercially-pure sheet is produced.

There are many difficulties in the basic fabrication of titanium. It is difficult to roll, less reduction being produced for a given load than with stainless steel. It is liable to gaseous contamination, so that electric furnaces must be used and preheating temperatures limited. It has a low heat capacity and thus loses heat rapidly during hot working. It is corrosion resistant and descaling to remove the oxide layer is difficult. It is expensive and thus every effort must be made to ensure a high yield of finished material.

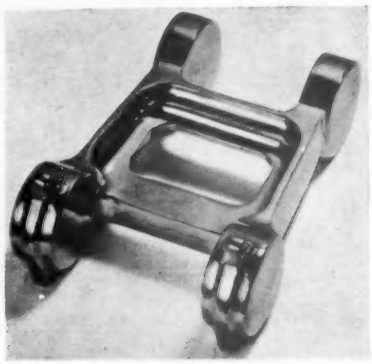
At Waunarlwydd rod is produced by hot rolling and finished by guide rolling with a Swedish Morgardshammar finishing mill. Guide rolling was chosen to increase the yield, to ensure accuracy and because roller guides are considered essential to success in rolling titanium.

Commercially-pure sheet is cold rolled to gauge sizes with intermediate annealing. Alloy sheet is hot rolled at all stages.

Nimonic Extrusion

Originally the Nimonic alloys were forged or machined, but today extrusion is used in their fabrication by Henry Wiggin and Co., Ltd., who produce the alloys. Extrusion is by the Sejournet process, in which molten glass is used as a die lubricant. This process has cut production time and costs; Nimonic can be extruded to bar with properties as good as those obtained if it had been forged. Even Nimonic 100 can easily be extruded.

In the new Wiggin factory at Hereford a 5,000-ton press is used for Nimonic extrusion. The process is even used for sheet production; ingots are extruded to form slabs which are rolled into sheet.



This 9-lb. precision forging in titanium alloy was produced by High Duty Alloys, Ltd.

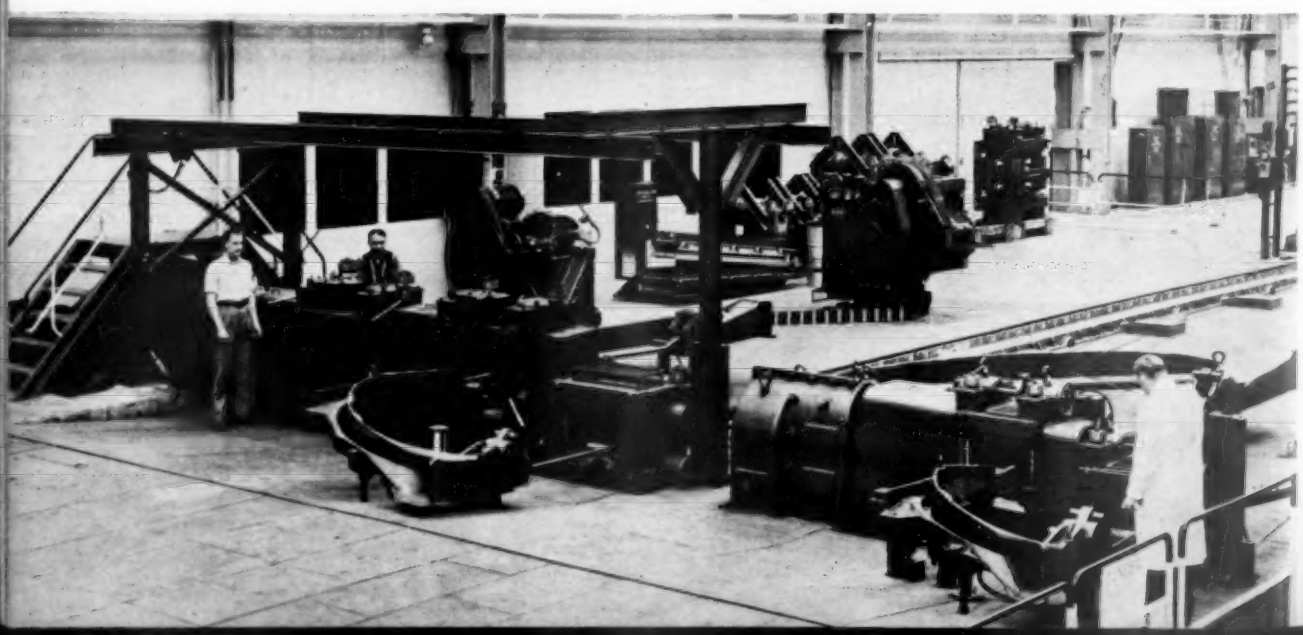
One of the latest developments in magnesium fabrication to be applied in the aircraft and missile fields is the production of magnesium-alloy castings with small-bore cored passages. This technique, developed by Magnesium Elektron, Ltd., can be used to produce castings with intricate internal passages. The path of a cast hydraulic line, for example, can be straight, circular or curved irregularly. Cast passages have smooth walls and may have rounded corners to improve fluid flow. Proper design can give weight and space saving and reduce machining time.

Both lined and unlined passages can be produced. Lined passages in magnesium castings have been made with stainless-steel tubing which remains in the casting. Inherent problems of machining and the possibility of electrolytic action, however, favour the use of unlined passages. These involve the use of steel, copper or glass tubing which is dissolved after the casting is produced by passing suitable acids through it. Copper and glass tubing is sheathed; removal of the sheath enables a check to be made that the tube has been fully dissolved. Removal of unsheathed tubes is checked by X-ray inspection.

The smallest diameter at present considered practicable for long passages is $\frac{1}{4}$ in. Unsupported $\frac{1}{8}$-in cores up to 24 in. long have been used.

Accles and Pollock, Ltd., are using a 500-ton hydraulic press for development work on the impact extrusion of tubes and bars in various sections. Different metals and alloys are being studied. Work is being concentrated, however, on the development of longitudinally-finned tube for the canning of uranium for nuclear reactors.

The advances in fabrication techniques which have been introduced to meet aircraft-industry needs often find wider applications. In this indirect fashion the aircraft industry makes a big contribution to advancing the techniques of British industry as a whole.



At the I.C.I. Waunarlwydd titanium plant this five-stand Morgardshammar guide mill hot-rolls titanium rod down to 0.25 in. in diameter.

Suppliers of Basic Materials and Associated Equipment

Abbey Panel and Sheet Metal Co., Ltd., Little Heath, Coventry.

Specialists in panel work, aircraft fabrications and assemblies. A.I.D. and A.R.B. approved, the company undertakes prototype and experimental work.

Accles and Pollock, Ltd., Oldbury, Birmingham.

Manufacturers of a wide range of tubes in ferrous and non-ferrous metals, including precision tubes in special metals such as zirconium and titanium. Products cover carbon and alloy seamless steel tubes; drawn welded low-carbon steel tubes; stainless steel and non-ferrous units, and non-circular tubes.

Aeroplastics, Ltd., Hillington, Glasgow, S.W.2.

Specialists in the production of moulded components, glass-fibre fabrications and packing materials.

Aero Research, Ltd., Duxford, Cambs.

Manufacturers of synthetic resins, synthetic-resin adhesives and metal honeycomb core for sandwich structures. Applications for the aircraft industry include Redex and Hidux adhesives for bonding metal structures and other materials; Aeroweb metal honeycomb; Aerolite glues for wood, and Araldite epoxy resins for bonding, laminated plastic structures and surface cratings.

Aluminium Corporation, Ltd., Dolgarrog, Conway, Caernarvonshire.

Producers of sheet, coiled strip, circles and matting in pure aluminium and aluminium-manganese, aluminium - magnesium and aluminium-nickel alloys. These materials are manufactured to Admiralty, M.o.S., A.I.D., A.R.B., and British Standards Institution specifications.

Andrews Toledo, Ltd., Toledo Steelworks, Sheffield, 3.

Producers of a wide range of aircraft steels.

Attewell, B., and Sons, Ltd., Iver, Bucks.

R.L.A. laminated aluminium for precision-adjustment requirements such as shims for aircraft applications. Manufactured from commercially pure aluminium, R.L.A. shims consist of a number of layers of aluminium foil bonded together.

Bakelite, Ltd., 12-18 Grosvenor Gardens, London, S.W.1.

Bakelite plastics; moulding materials; laminated sheet, rod and tube; polyester and epoxide resins; Vybake vinyl resins and compounds; Bakelite polyethylene; Warerite laminated plastics.

Balfour, Arthur, and Co., Ltd., Capital Steel Works, Sheffield, 3.

Producers of high-speed steels, alloy tool steels and plain carbon tool steels in bar and forging form.

Bambergers, Ltd., Finsbury Square, London, E.C.2.

Specialists in the supply of hardwoods, softwoods and plywoods for use in aircraft construction.

B.B. Chemical Co., Ltd., Ulverscroft Road, Leicester.

Bostik adhesive and sealing compounds of all types for sealing integral fuel tanks and pressure cabins.

Bell's Asbestos and Engineering, Ltd., Slough, Bucks.

Manufacturers of bulkhead fire seals, bedding tapes and sealing strip; asbestos gaskets for high-temperature joints, and asbestos air hoses for heating systems.

Birkbys, Ltd., Baker St., London, W.1.

Manufacturers of Elo plastic mouldings, phenolic synthetic resins and cements, and friction materials.

Birkett, T. M., Billington and Newton, Ltd., Hanley, Stoke-on-Trent.

Non-ferrous castings and machine parts. Birso chill-cast rods and tubes.

Birmetals, Ltd., Quinton, Birmingham, 32.

A complete range of wrought aluminium-alloy semi-fabrications such as sheet, strip, plate and sections, both solid and hollow; round and shaped tubes and wire. These are produced in all the wrought-aluminium specifications, both British Standards Institution and D.T.D.

In addition the company covers the range of wrought products in magnesium base alloys.

Birmingham Aluminium Casting (1903) Co., Ltd., Birmid Works, Smethwick, Birmingham.

Produces aluminium, magnesium and zinc-base castings by sand, gravity die- and pressure die-casting processes.

Bolton, Thomas, and Sons, Ltd., Copper Works, Widnes, Lancashire.

Producers of copper, brass and bronze.

Booth, James, and Co., Ltd., Nechells, Birmingham, 7.

Pioneers in the development of aluminium alloys in this country and suppliers to most of the leading aircraft manufacturers. Products include large forgings in aluminium, brass and magnesium; and non-heat-treated and single- and double-heat-treated aluminium alloys.

Both the mealtime tray and the serving tray are made from Cobex, a product of BX Plastics, Ltd. The latter is in wood-grained Cobex.

Bramah, J. R., and Co., Ltd., Devonshire St., Sheffield, 3.

Precision sheetmetal engineers producing a wide range of aero-engine details and airframe components, including titanium fabrications.

These include mild and stainless steel and light-alloy ducts; engine exhaust manifolds; access doors; jet-pipe shrouds; tanks for all services, and fire-proof panels.

Units produced from titanium cover helicopter engine cowlings and auxiliary aircraft tanks, and various types of ducting.

Britannia Tube Co., Ltd., Glover St., Birmingham.

Manufactures aluminium and alloy tubes and sections.

British Aluminium Co., Ltd., The, St. James's Square, London, S.W.1.

Suppliers and manufacturers of aluminium and aluminium alloys to D.T.D. and British Standards Institution specifications. In particular, sheet, strip, extruded bars and sections, and plate to aircraft specifications.

British Artid Plastics, Ltd., Trading Estate, Slough, Bucks.

Mouldings in thermo-plastic and thermo-setting materials.

British Moulded Plastics, Ltd., Avenue Works, Walthamstow Avenue, London, E.4.

Makers of Teldenduron titanium asbestos compound and mouldings; moulded plastics of all types.

British Nylon Spinners, Ltd., Pontypool, Monmouthshire.

This company manufactures nylon yarns and staple fibre, and supplies these products for use in the aircraft industry. Applications for nylon include tyres, parachutes, safety belts and clothing, petrol tanks and upholstery.

British Plywood Manufacturers, Ltd., Ponders End, Middx.

Manufacturers of high-strength aircraft birch plywood in accordance with specification 6V3, both for standard 90° and 45° diagonal constructions. Lower-strength aircraft plywood in spruce or gaboon conforming to specification V.35.

British Refrasil Co., Ltd., Stillington, nr. Stockton-on-Tees, Co. Durham.

Precision sheet-metal workers in stainless steel.

British Resin Products, Ltd., Devonshire House, Piccadilly, London, W.1.

Producers of synthetic resins and resin adhesives.

Brown Bayley Steels, Ltd., Riverdale Rd., Sheffield, 10.

Approved manufacturers of aircraft steels to the latest specifications.

David Brown Industries, Ltd., Foundries Division, Penistone, nr. Sheffield.

Aircraft quality high-tensile and heat-resisting steel castings; precision steel castings by the investment process; Taurus bronze castings and centrifugal castings for high-temperature applications.

B.S.A. Co., Ltd., Birmingham, 11.

Produces forgings, stampings and precision castings, including machined gas-turbine blades. The company also manufactures ferrous and non-ferrous metal products.

Burnley Aircraft Products, Ltd., Fulledge Works, Burnley, Lancs.

Specialists in sheet-metal and welded-steel components.

Bury Felt Manufacturing Co., Ltd., Hudcar Mills, Bury, Lancs.

Suppliers of felt in the form of washers, gaskets and sealing strips for use by the aircraft industry. The company also produces felt in large quantities for packing purposes.

Bushing Co., Ltd., The, Hebburn-on-Tyne, Co. Durham.

Texolex synthetic resin-bonded laminated paper and fabric sheets, tubes, machine parts and reinforced mouldings.

A close up of the 5,000-ton press at The British Aluminium Co., Ltd. establishment at Latchford Locks, Warrington.

Materials and Processes . . . .

B.X. Plastics, Ltd., Chingford, London, E.4.

Manufacturers of Cobex rigid vinyl sheeting and Velbex P.V.C. sheeting. Cobex is employed for moulded airline equipment such as passenger meal-trays, toilet units and similar fittings.

Velbex P.V.C. sheeting is used for aircraft panels and decorative headboards, and wrappings for engine components.

Carlisle, C. G., and Co., Ltd., Iona Steel Works, Sheffield.

Manufacturers of all types of stainless, heat-resisting and alloy steels, including round, square and hexagon bars.

Clifford, Charles, Ltd., Dogpool Mills, Birmingham, 30.

Manufacturers of non-ferrous metals in sheet, strip, rod, wire, tubes and chill-cast bars. Specialists in the production of phosphor bronze, aluminium bronze and other wrought high-tensile alloys in the form of rod and bar; brass and copper sheets and strip; phosphor-bronze strip, and brass and copper tubes.

Cork Manufacturing Co., Ltd., South Chingford, London, E.4.

Basic materials produced by this company cover a range of synthetic and natural rubber, and cork jointing materials, including Neolangite, which is used in the aircraft industry. Having a good resistance to normal lubricating oils, Neolangite can be used with gas-turbine fuels.

Cornercroft, Ltd., Ace Works, Coventry.

Manufactures jigs, press tools, special-process machines, gauges, assembly fixtures, sheet-metalwork components and special equipment for the aircraft industry.

Daleman, Richard, Ltd., Latimer Rd., London, W.10.

Evolite ærglic tubes and cylinders, rod and machine work, precision engraving to A.I.D. requirements.

Darwins, Ltd., Tinsley, Sheffield, 9.

The aircraft industry uses a wide range of castings, alloys, steels and tools manufactured by the Darwins Group. These include various types of steels, die- and precision-castings, and alloy forgings.

Deritend Precision Castings, Ltd., Vines Lane, Droitwich Spa, Worcs.

Produces investment castings by the lost-wax process and approved by M.o.S. for the production of high-tensile steel castings to specifications DTD 666, 705 and 5072. A considerable proportion of the company's output consists of aircraft castings in heat-resistant, stainless and carbon-alloy steels.

Dexion, Ltd., Maygrove Rd., London, N.W.6.

Slotted angle for constructing staging, maintenance docks and jig and tool assemblies. Used in the aircraft industry for a wide range of fabrications from factory stores to research and development applications.

Precision impeller forgings manufactured by the Dudley Drop Forging Co., Ltd., of Dudley

Nimonic alloy rings produced by mandrel forging by Daniel Doncaster and Sons, Ltd., of Sheffield.

Diecastings, Ltd., Highgate Square, Birmingham, 12.

Producers of gravity die and sand castings in aluminium, brass and bronze alloys.

Doncaster, Daniel, and Sons, Ltd., Penistone Rd., Sheffield, 6.

Engaged in the advanced manipulation of wrought materials, including the forging of titanium and other special metals and alloys used in the aircraft industry.

Equipped with a wide range of steam forging hammers; extrusion presses; friction-screw presses, and machining tools, the company produces titanium gas-turbine compressor blades and discs; Nimonic alloy rotor blades, and stainless and heat-resisting steels; components for aircraft.

Dudley Drop Forging Co., Ltd., Dudley, Worcs.

Producers of die forgings from a net weight of 1 oz. to 75 lb. in carbon, alloy and stainless steels; the Nimonic range of heat-resisting alloys; titanium, and copper alloys.

Components include steel forgings for aero-engines; alloy steel airframe forgings; impeller forgings, and titanium forgings for experimental undercarriages.

Dunlop Rubber Co., Ltd. (Aviation Division), Foleshill, Coventry.

Producers of six basic groups of rubber compounds, each divided into 10 grades. These individual specifications are standard with guaranteed characteristics and cover resilient rubbers based on natural rubbers; a group suitable for metal bonding; general purpose neoprenes which have a high resistance to mineral base oils, and nitrile content rubbers. The company also manufactures silicones.

Equator Wheels and Sections, Ltd., Raglan St., Wolverhampton.

Manufacturers of stainless-steel stiffening bands for gas turbines; cold rolling, forming and coiling in all metals.

Expanded Rubber Co., Ltd., Mitcham Rd., Croydon, Surrey.

Manufactures expanded nitrile Onazote, which is used in the construction of radomes. Employed as a core material with glass fibre as a facing material either in a single or double sandwich, expanded nitrile Onazote is available in three grades for radome manufacture.

The material is also used in the construction of aircraft floor panels and bulkheads.

Ferodo, Ltd., Chapel-en-le-Frith, Stockport.

Friction materials for use in aircraft brakes, friction discs and locking washers for control systems, rubber strips, and clutch and brake linings for the actuators of mechanical services.

One of the company's latest activities is the manufacture of sintered metal and cerametallic friction materials for compact clutches and aircraft disc-brake pads.

Ferro Enamels, Ltd., Wombourn, Wolverhampton.

Produces high-temperature coatings, including Solaramic for nickel-chrome alloys and mild steel for the aircraft industry.

Fibreglass, Ltd., Ravenhead, St. Helens, Lancs.

Produces Fibreglass insulation materials for aircraft applications. Available in two types, it is of very fine glass fibres bonded with phenolic resin to form a lightweight mat. The company also manufactures glass of different compositions in continuous filament form and converts this to weaving yarns, and yarns for the insulation of cables.

Fibreglass cloth is used to reinforce such components as radomes, air ducting and de-icing panels.

Fielding and Platt, Ltd., Atlas Works, Gloucester.

Manufacturers of hydraulic drawing, extrusion and forging presses, and stretch-forming machines.

Firth, Thos., and John Brown, Ltd., Atlas Works, Sheffield, 4.

Black and bright bars, billets, sheets and strip in high-speed and tool steels, carbon and alloy and special steels; forged steel cylinders, rings and other forgings for aircraft, gas-turbine and jet-propulsion units.

Firth-Derihon Stampings, Ltd., The, Tinsley, Sheffield, 9.

Manufacturers of drop forgings in creep-resisting steels, Nimonic alloys, titanium and special alloy steels for gas-turbine and rocket motors, and airframe components, including turbine and compressor discs, blades, shafts and propeller hubs.

Firth-Vickers Stainless Steels, Ltd., Staybrite Works, Sheffield, 9.

Staybrite, stainless, heat- and creep-resisting steels produced in the form of sheet, strip, and forgings.

The company manufactures castings by the centrifugal, centri-die, static and investment processes.

Flather, W. T., Ltd., Standard Steel Works, Tinsley, Sheffield.

Specialists in A.I.D.-tested aircraft steels. Manufactures bright steel bars, carbon and alloy steel to precision limits; drawn, turned or ground; case-hardening compounds and forgings.

Examples of Deritend Precision Castings, Ltd., investment castings produced by the lost-wax process.

Flexo Plywood Industries, Ltd., South Chingford, London, E.4.

Manufacturers of low-pressure plastics, resinated asbestos and glass fibre for the aircraft industry. In addition the company undertakes research and development work in this field.

Fothergill and Harvey (Sales), Ltd., Peter St., Manchester, 2.

Weavers of textiles, including Tyglas fabrics and rovings for glass-fibre reinforced plastic components.

Fox, Samuel, and Co., Ltd., Stocksbridge Works, nr. Sheffield.

Manufacturers of special and heat-resisting alloy and stainless steels for gas turbines, aircraft structures and guided missiles. Supplied as billet and bars, sheets, strip and wire.

Fry's Metal Foundries, Ltd., Merton Abbey, London, S.W.19.

Fryolux solder paint for tinning and sweat soldering.

Garringtons, Ltd., Newton Works, Bromsgrove, Worcestershire.

Produces all types of close-limit precision and upset drop-forgings.

General Electric Co., Ltd., The, Kingsway, London, W.C.2.
Makes a heavy alloy of high density for control-surface balance weights.

Gloster Engineering (Cheltenham), Ltd., Cheltenham.
Produces aircraft tools in laminated materials and glass-fibre laminates; router templates and jigs; rubber press dies and assembly jigs.

Godden, M. H. (Cheltenham), Ltd., Prestbury, Cheltenham, Glos.
Manufacturers of de-icing equipment.

Goodyear Tyre and Rubber Co., Ltd., Bushbury, Wolverhampton.
Produce erosion-resistant coating systems and chloroprene jointing compounds.

Habershon, J. J., and Sons, Ltd., Holmes Mills, Rotherham, Yorks.
Producers of hot- and cold-rolled steel strip, sheets, bars and sections to A.I.D. specifications.

Hadfields, Ltd., East Hecla Works, Sheffield, 9.
Components manufactured by this company cover steel castings and forgings; turbine discs; stator rings for exhaust-gas turbines; precision castings, stainless steels and shell-moulded castings.
Using a wide range of alloy steels, castings are produced for engine-mounting and guided-missile components, hollow blades and nozzle guide vanes, and highly stressed units such as undercarriage components.

Hall and Hall, Ltd., Hampton, Middx.
Manufactures various types of packings and jointings. These include Hallprene synthetic rubbers produced from various bases such as Neoprene, Butyl and Silicones; Hallite jointing materials, moulded packings and fluid seals.

Hall and Pickles, Ltd., Port St., Manchester, 1.
Produces tool steels, cutting steels, stainless and heat-resisting steels and special-purpose wire. At the company's Hydro Steel Works, Sheffield, a wide range of high-speed steels, press tool and cold die steels, and alloy and carbon tool steels, are manufactured.

High Duty Alloys, Ltd., Slough, Bucks.
Manufacturers of Hiduminium (aluminium) and Magnuminium (magnesium) alloys in the form of castings, forgings, stampings, pressings, extrusions, sheet and fabrications. The company also produces precision forgings in titanium for the aircraft industry.

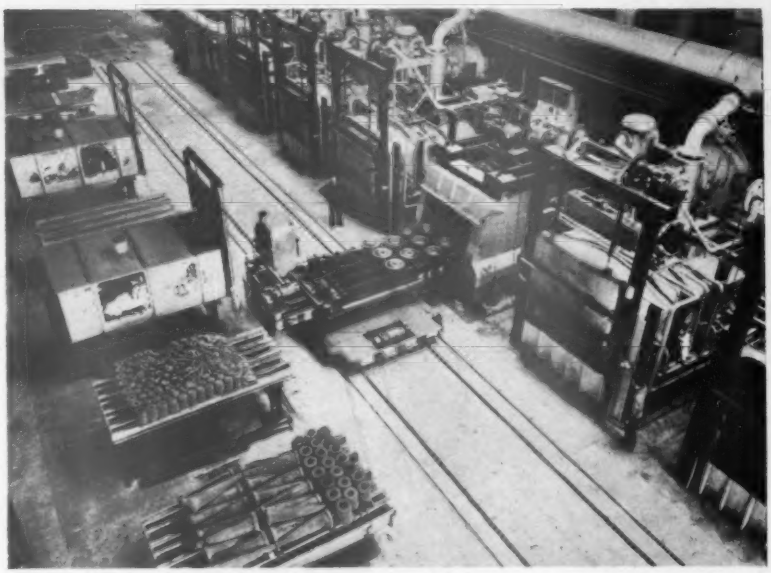
Hoyt Metal Co. of Great Britain, Ltd., Putney, London, S.W.15.
Manufactures zinc-base casting alloys and Kirksite press tools.

Hughes-Johnson Stampings, Ltd., The, Langley Green, Birmingham.
Drop forgings in carbon and alloy steels, copper bronze, brass and aluminium alloys, magnesium, high nickel chrome, non-ferrous alloys and titanium.

Imperial Chemical Industries, Ltd. (Metals Division), Kynock Works, Witton, Birmingham, 6.
This division of I.C.I. manufactures ranges of non-ferrous metals for engine components, heat exchangers, fuel systems, electrical and control systems, and cabin furnishings.
These cover Kynal aluminium alloys sheet and strip, extrusions and forgings; copper and copper alloys and titanium.

Imperial Chemical Industries, Ltd. (Plastics Division), Welwyn Garden City, Herts.
The Plastics Division of I.C.I. manufactures a wide range of materials for the aircraft industry. These include Perspex acrylic sheet for cockpit canopies and similar aircraft transparencies; reinforced plastic laminates for radomes and aerial panels; Welvic polyvinyl chloride compounds, polythene and silicone resins for electrical insulating applications, and other plastics for moulded components.

Jessop, William, and Sons, Ltd., Brightside Works, Sheffield.
A principal supplier of raw material to the industry, the company is known for its Hylite range of titanium alloys and high-temperature steels for gas turbines.
One of the company's latest achievements is the production of vacuum-melted steel on a commercial scale, developed from the vacuum melting of titanium alloys.



The new heat-treating plant at the Sheffield works of The Firth-Derihon Stampings, Ltd. On the near side of the central rotating charging machine is the range of loading tables, slow-cooling chambers and forced air cooling table. On the far side are the furnaces and the control house.

Kautex, Ltd., Elstree, Herts.
Produces Neoprene bonded cork to M.o.S. specification D.T.D. 762, and synthetic and natural rubber mouldings.

Kaye, E. and E., Ltd., Enfield, Middx.
Manufacturers of aluminium-alloy extruded products and drawn tubing from the raw ingot metal. Produced under the trade names of Durcilium and Alumagnese, these alloys are used for a number of aircraft applications.

Kayser, Ellison and Co., Ltd., Carlisle Steel Works, Sheffield, 4.
Special steels for die casting and hot work; tool steels used in presses and cold-forming tools, and steels such as KE.40 A.M. stainless iron employed in the manufacture of instrument components.

Kenilworth Manufacturing Co., Ltd., Hermetite Works, West Drayton, Middx.
Hermetite range of jointing/sealing compounds to A.I.D. and A.R.B. requirements. New Hermetal Double Bond epoxy-based chemically curing filler for moulding and jig jointing.

Kent Alloys, Ltd., Temple Manor Works, Rochester, Kent.
Comprehensive facilities for the production of cast machine parts, including pattern and core-making, pouring and heat treatment, machining and inspection.
The company produces castings in ferrous, copper, magnesium, and aluminium alloys, besides Elektron alloys, and maintains radiological and gamma-ray laboratories for the radiographical examination of metals and welded assemblies.

Ultrasonic inspection of a large titanium slab at the Brightside Works of William Jessop and Sons, Ltd., Sheffield.

Klinger, Richard, Ltd., Sidcup, Kent.
Produces high-pressure jointing materials and high-temperature gaskets and sheets. One of the company's latest developments is Klinger 721, a compressed asbestos jointing material for use with synthetic lubricants and fuels.

Langley Alloys, Ltd., Langley, Slough, Bucks.
This company specializes in the manufacture of high-duty bronzes and the bulk of its supplies to the aircraft industry have been in the range of Hidurax aluminium bronzes and Hidurel 5, a high-strength alloy.
Over the past few years the company has entered the field of heat-resisting alloys and can supply a range of cast chromium-nickel steels, both sand- and shell-moulded.

Lavender, J. H., and Co., Ltd., Hall Green Works, West Bromwich.
A.I.D.-approved manufacturers of sand, gravity and pressure die castings in aluminium alloys.

Lee, Arthur, and Sons, Ltd., Trubrite Steel Works, Meadow Lane, Sheffield.
Bright drawn carbon and alloy-steel bars; steel strip, wire, and so on.

Leicester, Lovell and Co., Ltd., North Baddesley, Southampton.
Epoxide resins for plastic tooling such as moulds, drilling jigs and drop-hammer tools.
In the aircraft industry Epophen epoxide resins are employed for the production of such units as plastic radomes, stainless-steel pressings and other similar components.

Light-Metal Forgings, Ltd., Churchbridge, Oldbury, near Birmingham.
Drop forgers and stampers in aluminium alloys.

London Aluminium Co., Ltd., Witton, Birmingham, 6.
Pressings, spinnings, stampings; high-quality sheet; ferrous and non-ferrous metal-workers; coppersmiths, and component manufacturers.

Low Moor Alloy Steelworks, Ltd., Low Moor, Bradford.
Producers of stainless and heat-resisting steels to A.I.D. and other standards, in all forms of bar.

Materials and Processes . . . .

Magnesium Elektron, Ltd., Swinton, Manchester.

Manufacturers of the range of Elektron ultra-light magnesium alloys which are used in the aircraft and other industries. Products include general-purpose high-proof stress structural alloys for undercarriages; alloys for aero-engine castings, and alloy sheets for aircraft skinning.

Mills, William, Ltd., Friar Park Road, Wednesbury, Staffs.

This company produces aluminium-alloy castings by the sand and gravity die and pressure methods.

Mining and Chemical Products, Ltd., Strand, London, W.C.2.

Manufactures and supplies metals and fusible alloys, such as Cerromatrix, Cerrobend and Cerrotru, for aircraft jigs, tube and section binding, fusible cores, mandrels for electroforming wave guides, moulds for thermoplastics, resin and lost-wax processes.

Also high-purity metals and semi-conductor materials including bismuth, aluminium, arsenic and bismuth telluride.

Minnesota Mining and Manufacturing Co., Ltd., Wigmore St., London, W.1.

A range of adhesives, coatings and sealers for aircraft requirements. These include adhesives for bonding plastics and rubbers to metal; erosion-resistant, anti-glare and non-skid paints, and sealing compounds for pressure joints, weatherproofing and canopies.

Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W.1.

Refiners of nickel.

Morgan, George, Ltd., Selly Oak, Birmingham.

Specialists in the making of drop forgings in alloy and carbon steels; the company's products include precision forgings for the aircraft industry.

Also equipped to undertake a wide range of heat-treatment processes covering annealing, normalizing, hardening and tempering.

Morgan Crucible Co., Ltd., The, Battersea Church Rd., London, S.W.11.

Sinterlink metal friction materials for clutch and brake applications. A synthetic material consisting mainly of metal powders with the addition of solid lubricants and friction elements, compressed and sintered to provide self-lubricating friction material. Sinterlink is bonded to a steel backing to form a friction plate.

The company also manufactures Crusilite electric furnace elements.

Nitralloy, Ltd., Atlas Works, Sheffield, 4.

Nitriding process of case-hardening special steels by nitrogen and the production of Nitralloy steels for use with the Nitriding process.

Nobrac-Carbon, Ltd., Lancing, Sussex.

Manufacturers of mechanical carbons, bearings and sealing-ring materials for high-temperature conditions, and special products.

North British Plastics, Ltd., Blaydon, Co. Durham.

Manufacturers of paper-based resin-bonded laminated plastic sheeting which is used in the aircraft industry in the production of rubber die press tools; Hufford stretch-forming tools; router jigs and templates, and other similar applications.

Northern Aluminium Co., Ltd., Bush House, Aldwych, London, W.C.2.

Noral aluminium and aluminium-alloy products for aircraft manufacture, including ingots, sheet and strip; bars, rods and sections; extruded and drawn tubes; forgings and castings.

The company has recently extended its fabricating plant at Rogerstone by the installation of a new plate-stretcher for producing thick, stress-relieved aluminium-alloy plate for machining into integrally stiffened aircraft wing skins and similar components.

Omes, Ltd., Beverley Works, Barnes, London, S.W.13.

Manufacturers of resistance-heating equipment for forging; electrically upset forgings and gas-turbine blade forgings.

Parkes, L. B., and Co., Walsall.

Specialize in the anodizing and cadmium plating of irregular large-size fabrications such as very long extrusions and large sheet-metal components.

Perry Barr Metal Co., Ltd., Shady Lane, Great Barr, Birmingham, 22a.

Supplies aluminium sand and die castings to the aircraft industry.

The company also machines and assembles castings as a sub-contractor of Rotol, Ltd., and its products cover sand-cast clutch housings for the Alvis Leonides powerplant, and castings used in the Bristol Britannia.

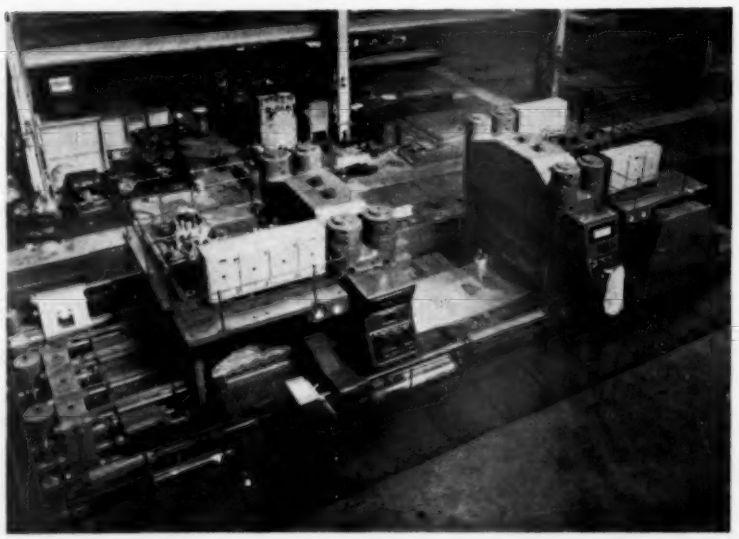
Reynolds T.I. Aluminium, Ltd., Tyseley, Birmingham, 11.

Produces aluminium and aluminium-alloy plate, sheet, strip, extrusions and tubes to all aircraft materials specifications. The company has its extrusion, bar and tube works at Redditch and its rolling mills at Resolven.

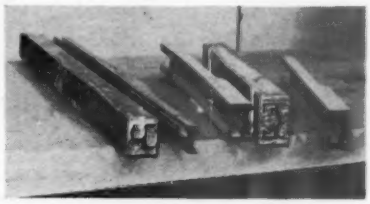
Reynolds Tube Co., Ltd., Hay Hall Works, Tyseley, Birmingham, 11.

Seamless steel tubing, manipulated steel and light-alloy tubes and sections; aircraft structures such as engine mountings; ground equipment; fabrication of structures incorporating aluminium-alloy tubes, extrusions and sheet.

Flush butt-welded rings in stainless steel and the Nimonic alloys.



A 4,000-ton plate stretcher which forms part of the new Noral plate production facilities installed at the Rogerstone works of the Northern Aluminium Co., Ltd.



Cerro alloys by Mining and Chemical Products, Ltd., are used to encapsulate extruded sections before bending.

Rollet, H., and Co., Ltd., 6 Chesham Place, London, S.W.1.

Stockists of all non-ferrous materials and stainless steels for aircraft experimental and prototype work.

Rubbaglas, Ltd., 66 Victoria St., London, S.W.1.

Manufacturers of specialized rubber products; processed glass; Rubbaglex sheeting and Silastic rubber mouldings.

Samlesbury Engineering, Ltd., Samlesbury Airfield, near Blackburn, Lancs.

Manufacturers of major aircraft components, structural assemblies, jigs, tools and fixtures. A.R.B.-approved design and drawing office.

Scott Bader and Co., Ltd., Wellingborough, Northants.

Marco and Crystic polyester resins for glass-reinforced radomes and fairings, and for the impregnation of porous metal castings.

Sheepbridge Alloy Castings, Ltd., Sutton-in-Ashfield, Notts.

Produces castings in high-alloy steel and nickel-base compositions utilizing both conventional foundry methods and specialized methods such as centrifugal casting and the more recently developed shell-moulding technique.

The main applications of these steels are in the fields of heat-resisting and corrosion-resisting components for gas-turbine construction.

Sheffield Forge and Rolling Mills Co., Ltd., Millsands, Sheffield, 3.

Manufacturers of aircraft steels.

Sheridan Machinery Co., Ltd., The, Lincoln House, High Holborn, London, W.C.1.

Manufacturers of production equipment for the aircraft industry. This range, which covers stretch-forming presses for accurately producing compound-contoured aircraft components from sheets, rolled sections and extrusions, is manufactured in both this country and the United States.

Siemens Edison Swan, Ltd., Charing Cross Rd., London, W.C.2.

Produces cables; copper wire; electrical accessories; moulded plastics units, and laboratory apparatus for use in industry.

Smethwick Drop Forgings, Ltd., Rolfe St., Smethwick.

Manufacturers of drop forgings.

Smith-Clayton Forge, Ltd., Tower Works, Lincoln.

Manufacturers of forgings and drop stampings.

Smith's Stamping Works (Coventry), Ltd., Humber Avenue, Coventry.

Drop forgings, upset machine forgings and press forgings in steels to all standard specifications.

Southern Forge, Ltd., Langley, Bucks.

Produces bars, rods, sections, tubes, forgings and stampings in Alminal aluminium alloys.

Steel Stampings, Ltd., Cookley, near Kidderminster, Worcs.

Stainless and other steel pressings; welded steel rings.

Stone, J., and Co. (Charlton), Ltd., Charlton, London, S.E.7.

Magnesium and aluminium alloys for general engineering and aircraft purposes and alloys for special applications.

Elektron magnesium alloy castings for aero-engine components; aircraft brake units; research rockets; electrical equipment such as generators, and canopy assemblies, and standard aluminium alloys for gravity die-cast, shell-moulded, cast and sand-cast components.

Stone and Co. (Deptford), Ltd., London, S.E.14.

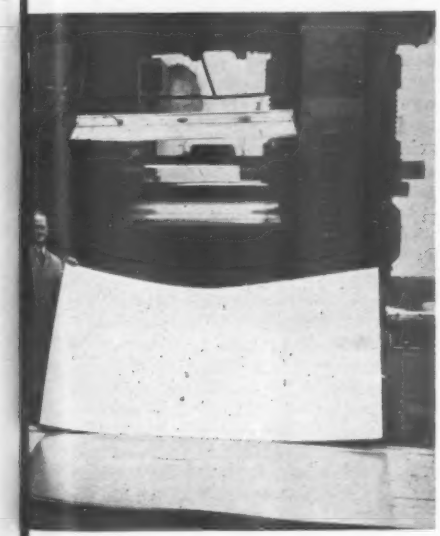
Products include non-ferrous rivets of all types and other fasteners.

Ta'bot Stead Tube Co., Ltd., Grun Lane, Walsall.

Manufacturers of stainless and heat-resisting steel tubes from ¼ in. to 6¾ in. outside diameter in wall thicknesses from 22 gauge. The company also has a large machine shop for producing small machined parts and processing of all metals.

Thermo-Plastics, Ltd., Luton Road Works, Dunstable.

Producers of plastic components for the aircraft industry from Perspex, p.v.c., resin-bonded glass fibre, asbestos and all thermo-plastic and thermo-setting materials.



Sheets of 8 ft. x 4 ft. x 20 s.w.g. commercially pure titanium to DTD 5023. Rolled at the Sheffield works of Titanium Metal and Alloys, Ltd., it is supplied with a cold rolled finish.

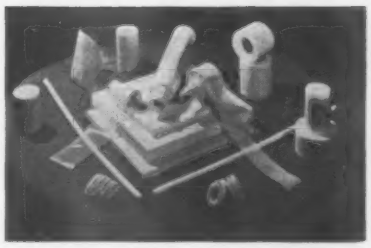
Titanium Metal and Alloys, Ltd., Clyde Steel Works, Sheffield, 3.

One of the first companies in this country to roll titanium bar and sheet, and its plant at Sheffield can roll a wide variety of sheet and bar sizes.

In addition to rolling, the company has facilities for forging and the general fabrication of titanium, and has rolled sheets of 8 ft. by 4 ft. by 20 s.w.g. commercially pure titanium to D.T.D. 5023 with a cold-rolled finish.

Triplex Safety Glass Co., Ltd., Albemarle St., London, W.1.

Manufacturers of all types of aircraft windows in safety glass including optically



Plastic raw materials used by Siemens Edison Swan, Ltd., of London in the production of electrical accessories.

polished flat and curved glasses, and mist- and ice-resisting glass coated with a transparent gold film.

This film, known as Triplex G.F. and applied to the inner face of one glass component so that it is protected from damage and completely insulated in the finished laminated panel, can carry up to 1,000 W./sq. ft. for heating the glass for de-icing or de-misting.

Trucast, Ltd., Farnham Royal Lodge, Bucks.

Investment castings in non-ferrous and ferrous alloys, including stainless, heat-resisting, high and low alloy steels; development of manufacturing processes and equipment.

Tufnol, Ltd., Perry Barr, Birmingham, 22b.

Manufacturers of Tufnol, which is normally supplied in its basic form as sheet, tube and rod. Used for a number of aircraft applications, including instrument panels and pulley assemblies, it is available in various brands.

Tungum Co., Ltd., The, Cheltenham, Glos.

Manufacturers of Tungum alloy tubes, rod and bar, wire, wire rope, castings, forgings, stampings, pressings and sheet.

United Steel Companies, Ltd., The, Westbourne Rd., Sheffield, 10.

The Steel, Peech and Tozer, Rotherham, branch of The United Steel Companies, Ltd., supplies steel rings to most of the principal aero-engine constructors.

These rings are hand forged, or rolled either in ring-rolling mill or, in the case of the larger sizes, in the railway-tyre rolling mill.

The company produces rings in plain carbon, alloy and stainless steels from 1-in. to 8-ft. diameter.

Vane, A. H., and Co., Empire House, St. Martin's-le-Grand, London, E.C.1.

Manufactures aircraft textiles and fabrics of all types for parachutes, windsocks and air targets; neoprene proofed fabrics, webbing and cords.

Vulcanised Fibre, Ltd., Bradford Mills, Guildford, Surrey.

Manufacturers of Castle vulcanized fibre sheets, rods and tubes.

Wallington Weston and Co., Ltd., Frome, Somerset.

Manufacturers of various types of plastic sheeting, including Fromo PLAS-N sheeting which is the company's main product used by the aircraft industry.

A rigid thermoplastic sheeting, Fromo PLAS-N is being employed in the Vickers Viscount, the Fokker Friendship and the Bristol Britannia.

Wiggin, Henry, and Co., Ltd., Wiggin St., Birmingham, 16.

Specialists in non-ferrous materials and a large producer of wrought nickel alloys.

In 1941 the company introduced the first of the heat-resisting Nimonic series of alloys for turbine rotor blades, which are also used for a wide range of other structural components as engine operating temperatures have risen.

Other Wiggin materials are the Nimocast high-temperature casting alloys for gas turbines, and Monel, Inconel, Ferry, Brightray and Nilo materials for use in airframes and accessories.

Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, Watford.

Specialists in heat-treatment equipment.

Wright, John, and Sons (Veneers), Ltd., Longfellow Rd., Mile End Rd., London, E.3.

A sand casting in aluminium alloy by J. Stone and Co. (Charlton), Ltd., of London.

Manufacturers of veneers to all specifications required in aircraft construction and interior decoration.

Yorkshire Copper Works, Ltd., Stourton, Leeds.

Solid-drawn tubes in copper, brass, aluminium brass, copper-nickel and other non-ferrous alloys. The company also manufactures tubes for aircraft oil and petrol systems; hydraulic equipment and instruments.

Young, A. S., and Co., Ltd., Woodside Lane, London, N.12.

Welding rods and Colmonoy hard-surface alloys, Nicrobraz high-temperature brazing alloys.

A bar of Nimonic 90 emerging from a 5,000-ton extrusion press prior to shearing by the 180-ton shears (on the right) at the Hereford works of Henry Wiggin and Co., Ltd.

Quotes from Luton

Aircraft ice protection was the subject of a conference held at the Flight Development Establishment of D. Napier and Son, Ltd., at Luton on June 11. Quotations from the five lectures follow. A few of the comments made by speakers in the discussions are also given.

"Icing Standards and Methods Used to Determine the Suitability of Aircraft to Fly in Icing Conditions," by H. E. Le Sueur, Air Registration Board.

"The flying test vehicle with provision for producing its own icing cloud has been developed and, although it has a number of limitations, it forms the best available means of testing equipment and aircraft components."

"The necessity for the fitment of ice detectors has not yet been fully resolved. There is one good argument in their favour and that is that a reliable ice detector will put the flight crew in a state of awareness."

"The basic requirement is that the aircraft should be demonstrated as capable of carrying a moderate accretion of ice. The only way to do this is to fly the aircraft into natural icing conditions."

"Hailstones 5¼ in. in diameter have been known to occur and it is imperative that steps should be taken to avoid the cores of thunderstorms. The installation of cloud and collision warning radar will go a long way to avoiding such conditions, but the equipment has not yet reached the stage where it can be regarded as 100% reliable and, what is more important, in its present form it requires constant vigilance on the part of the flight crew when flying near storm areas."

"Some Aspects of Engine Icing," by W. Sherlaw, Rolls-Royce, Ltd.

"The requirements of an engine de-icing or anti-icing system are now simple to express; they are: It must be effective and continue to be so. It must cost nothing in normal flight. The weight penalty must be the absolute minimum, i.e., whatever it weighs is too much."

"Some four million engine hours on the Dart engine, also cleared for A.R.B. icing conditions, have shown the electrical system of intake de-icing to be very satisfactory in service, particularly when it is considered that the system must be switched on before entering icing and the estimate of one operator is that it is used possibly for 20% of the time."

". . . fluid injection is by no means a competitive scheme to hot-air de-icing This is particularly so where cabin contamination is a problem."

"With regard to conduction, the very large temperature-gradients which it is possible to get, both chord and spanwise, in hollow-steel guide vanes has been a problem in obtaining maximum economy in the heating air flow for these components."

"A problem which concerns us particularly at the moment is that of protecting against rain erosion on heater pads and its operational necessity. There appears to be a difficulty of relating test to operational experience, and it would be very acceptable if operational experience showed that the problem has been exaggerated."

"Ice detectors are something which we have never been able to dissociate from engine icing. We have tested a wide variety both in embryo and finished state and are still testing them, hoping to find a fully suitable one."

"Electric or Hot Gas Thermal Ice Protection?" By J. A. Hay, Vickers-Armstrongs (Aircraft), Ltd.

"It is essential that any system fitted to an aircraft should be sufficiently rugged to withstand the rigours of normal operational service. In the case of the ice protection system, it must be capable of withstanding, amongst other things, the impact of rain, hail and stones."

". . . there is no supreme advantage of either thermal system over the other."

"The weights of the two systems are similar though the electrical system tends to be slightly the greater."

"Broadly speaking, the greater ease of installation of the electrical system has to be weighed against the rather better serviceability and lower maintenance requirements of the hot gas system, and the final choice must depend very largely on the particular application."

"In making this choice, the rôle of the aircraft, the available sources of heat, and the type and location of the components requiring protection must all be taken into account. In support of these remarks, it is worthwhile reflecting upon the increasing numbers of new types of civil aircraft which rely on hot gas ice protection of the mainplanes, whilst having cyclic electrical protection of the tail unit."

"Aircraft Electrical Heater Mats and Future Developments," by Dr. R. A. Roper, D. Napier and Son, Ltd.

". . . . after a heater mat has been designed, its manufacture is a question of meticulous attention to detail and the ultimate performance of the product depends largely on close control at every stage."

"For a complex shape, even when the mat is flexible, it is probably better to build the mat *in situ*."

"This system (an element of metal deposited from a flame spray-gun) has great advantages in the ease with which a complex design of circuit can be handled."

"The material which is used to sandwich the element must have good insulating properties, adequate adhesion to metallic surfaces—particularly light alloys—and in service must be impervious to water, aircraft fuels, oils and hydraulic fluids."

"Until recently it seemed that protection against high-speed rain and protection against hail and stones were incapable of a common solution. Developments in electro-plating techniques now enable extremely hard, yet flexible, films to be produced which show good resistance to both types of damage."

"Development of Ice Protection Control Systems," by E. O. Robertson, Canadian Applied Research, Ltd.

"To initiate icing protection and to discontinue such protection when the icing encounter is ended, a form of ice detector is necessary."

". . . it seems most likely that future aircraft having propulsion units grouped around the tail will have the problem of ducting vast quantities of hot gas forwards from the tail for mainplane ice protection unless designers resort to electro-thermal de-icing."

"No two aircraft constructors have the same ideas on de-icing control and many special features may be specified; these can include various forms of indication, both of correct operation and malfunction, and special circuits to prevent pad overheating on the ground."

DISCUSSION POINTS

It is preferable to perform de-icing demonstrations at specific temperatures, with a few degrees tolerance on either side. Temperature range is the interest, rather than a particular temperature.

Icing conditions can be more reliably found in summer than winter, by flying through the tops of cumulus clouds. There is more continuous ice in winter, but it is not always possible to get the aircraft off the ground.

It is best to have an openable direct-vision panel for the pilots as a safety measure.

Reliability is the criterion for an ice detector.

It is best to have a simple de-icing system selected by the pilot according to conditions of temperature.

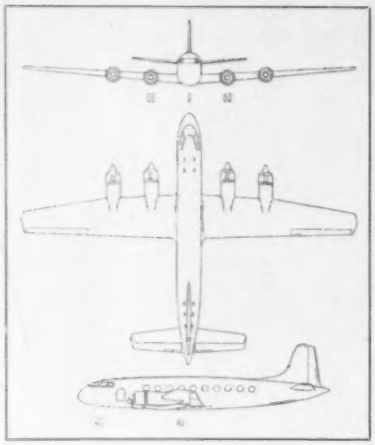
The weight of an ice protection system is dependent on the route flown and the time of year of the operations.

Porous skin has a very efficient heat-transfer, but the small pores may become blocked by ice or dirt.

Weight of a system might be halved by the use of automatic controls.

Reprints of the five papers, with discussions, will be available from D. Napier and Son, Ltd., to whom requests should be addressed.

A New Aircraft from Italy . . . .



FIRST FLIGHT of the Agusta AZ8L was on June 9 when it was airborne for 45 min. The AZ8L was designed by Dr. Filippo Zappata for the Agusta company, which also produces the Bell 47 helicopter under licence. It is powered by four Alvis Leonides 502 engines of 540 b.h.p. at take-off.

Up to 26 passengers or 2,800 kg. (6,170 lb.) of freight can be carried in this four-engined low-wing aeroplane which is being developed primarily as a civil type, although a military version is also available.

All-metal stressed-skin structure is used and the airframe is generally quite conventional. A hydraulically operated retractable tricycle undercarriage is fitted. Span and length are 83 ft. 8 in. and 63 ft. 9 in. respectively. The wing area is 719 sq. ft. and the aspect ratio is 9.78:1. Of the gross weight of 23,800 lb., 8,150 lb. is useful load. Maximum speed at sea-level is 260 m.p.h. and the sea-level cruising speed is 212 m.p.h. With a payload of 5,800 lb. the range is about 600 nautical miles in VFR conditions.

. . . . and One from East Germany

EAST GERMANY'S new jet airliner, the Baade-Bonin 152, should by now have flown. Only limited information is available about this new medium-range aircraft, which has been built at Dresden. It apparently owes much of its basic design to the Junkers EF-150 bomber, which was started before the end of the War and flew at Dresden in 1952. In size and performance the BB.152 lies between the Caravelle and the new D.H.121.

Although somewhat smaller, it appears to be in a similar class to the Tu-104; operation from small aerodromes should make it more flexible, however. A possible shortcoming is its use of a new and unproved engine.

The BB.152 has an all-up weight of 102,000 lb. and a cruising speed of 500 m.p.h. Its seating capacity is 48-72, depending on interior layout, and it is designed to operate over ranges of 1,250-1,850 miles. An interesting feature is its ability to take off and land from small airports; it is claimed that a runway less than 1,100 yd. long is needed.

The BB.152 is a high-wing aircraft with its wings swept at about 35°. Wing span is 84 ft. and length 103 ft. The aircraft has four 014 turbojet engines of East German design, slung under the wing in twin pods.

Photographs do not clearly reveal details of the undercarriage; a bicycle undercarriage with main wheels retracting into the fuselage is said to have been schemed originally and appears to have been used on the prototype BB.152. But this arrangement takes up fuselage space and is unsuitable for civil aircraft; Boeing did not use it for the 707 airliner despite considerable experience with the bicycle undercarriages of the B-47 and B-52 bombers. Models of the BB.152 shown at the Leipzig Fair recently had a tricycle undercarriage with the main units retracting into the engine pods.

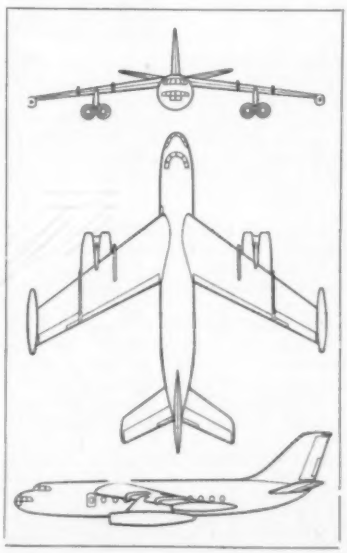
The 014 turbojet engine has been developed in East Germany. It has a 12-stage axial compressor, an annular combustion chamber and a two-stage turbine. Take-off thrust is 6,930 lb. and specific fuel consumption 0.85 lb./lb./hr. Its electric starter motor acts as a generator during flight.

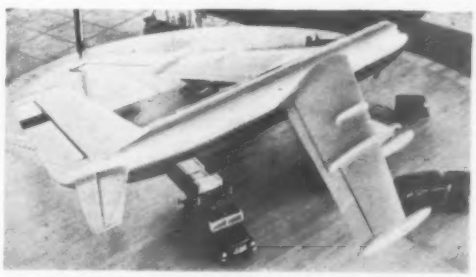
Normal seating in the cabin is for 57 passengers, but a tourist layout will seat 72. A special first-class layout seats 48. The aircraft cruises at 33,000-40,000 ft.; the pressurization system holds the effective cabin altitude at 6,500 ft. The cabin windows are larger than those of the new generation of Western turbojet airliners.

Crew of the aircraft is four. As well as the passenger cabin, the fuselage has luggage and freight compartments, a wardrobe, a galley and two toilets.

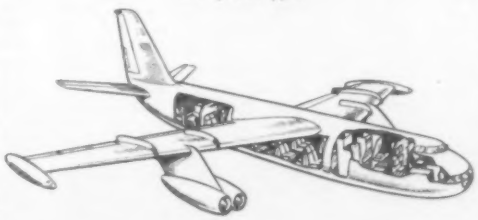
The BB.152 is intended for operation by the East German Lufthansa airline, beginning in 1960. It will also be produced for export. Orders from Western countries would appear unlikely but South American, Middle East and Asian countries, the manufacturers hope, will be interested. Behind the Iron Curtain, the Balkan States, Russia and China form a potential market.

The accompanying drawings of the BB.152 are of the first prototype which has the temporary bicycle arrangement of the main wheels.





Models of the BB.152 at the Leipzig Fair (above) showed a different undercarriage layout compared with that of the prototype.



Military Aviation Affairs

MESS DRESS.—Air Commandant Barnett, director of the W.R.A.F., admires the new mess dress for W.R.A.F. officers worn by Wg. Officer D. von Donop. On the right is Flt. Lt. McC. Wallace, wearing R.A.F. officer's mess dress.

ROYAL PROMOTION.—The Duke of Gloucester has been promoted from Air Chief Marshal to Marshal of the Royal Air Force. Appointed to the R.A.F. in 1937 as an Air Vice-Marshal, he became an Air Marshal in 1941, and has held the rank of Air Chief Marshal since 1944.

NAVAL PUNCH. — The Royal Canadian Navy is to equip its McDonnell F2H-3 Banshees with Sidewinder air-to-air missiles.

COMET EXPERIENCE.—Wg. Cdr. I. D. N. Lawson, D.F.C., O.C., No. 216 Sqn., accompanied by navigation and engineering specialists from Headquarters, Bomber Command, and R.A.F. Lyneham, recently flew the new D.H. Comet 4 G-APDA, the first of 19 on order for B.O.A.C. The Comet 2s of No. 216 Sqn. have now logged more than 11,000 hr., the overall total of Comet flying being 50,000 hr.

LAST BEVERLEY.—The last of the 47 Blackburn Beverleys for the R.A.F. left Brough recently. This type is now in service with Nos. 30, 47, 53 and 84 Sqns. Deliveries began just over two years ago.

CENTENNIAL CELEBRATIONS.—Due to return to the U.K. this week-end an R.A.F. detachment of two Vulcans from No. 83 Sqn. (Wg. Cdr. L. F. Banks, D.F.C., A.F.C.) at R.A.F. Waddington supported by No. 99 Sqn. (Sqn. Ldr. T. M. Stafford) Hastings, had been taking part in the British Columbia Centennial Celebrations at Vancouver earlier this month. Commanded by A.V.M. G. A. Walker, A.O.C., No. 1 Group, the Force made a number of demonstration flights and the aircraft were shown in static displays.

News About People

D. H. EXPORTS.—Mr. C. S. Thom has been appointed by de Havilland Holdings, Ltd., to assist in co-ordinating the export and other overseas interests of the de Havilland companies. His experience will now be applied in a broader field and he has relinquished his position as Sales Director of The de Havilland Aircraft Co., Ltd.

MASTERADIO POST.—Gp. Capt. L. R. Ridley, O.B.E., assistant director, Electronics Research and Development at the M.o.S. for the past four years, has retired from the R.A.F. to join Masteradio, Ltd., and its subsidiary, R.M. Electronics. He is to be responsible for the company's radar and electronics division. Masteradio is a member of the Francis Sumner Group.

S.L.A.E. OFFICERS.—At the recent A.G.M. of the Society of Licensed Aircraft Engineers, Mr. M. T. Holdham was installed as president of the society for 1958-60 and Mr. I. J. Gregory as vice-president. Appointed officers of the General Council of the Society for 1958-59 are: chairman, Mr. M. T. Holdham; vice-chairman, Mr. A. T. Paterson; honorary treasurer, Mr. S. Davis; honorary secretary, Mr. D. W. Richardson; honorary registrars, Mr. T. F. Barnett-Higgins and Mr. W. W. Gilham.

"Ah, now we're getting somewhere—that's the exact opposite of the cabin layout that my airline wants."

SHOREHAM PRIZEWINNERS.—At the recent R.Ae.C. invitation air rally at Shoreham, Col. C. F. H. Gough presented the prizes to some of the rallyists. They were: **Tankards:** M. Plouviers (*Belgium*); Mr. Wayman-Hales (*Ireland*); Baron Wedell-Wedellsborg (*Denmark*); Mr. Strange-Hansen (longest distance flown to the Rally); M. D. Lacker (*France*); Lt.-Col. R. Teyssier (*U.S.A.*); Mr. Oberman (*Holland*); Lt. E. Meille (*Italy*). **Sealed Time of Arrival:** Maj. Pelham Reid. **Largest party arriving by Air:** Mr. J. B. Peak. **Longest Rally attender:** Mr. H. Deterding.

PRIVATE FLYING. — As H.J.C. is on holiday his weekly Club Commentary is being held over until his return.

MARCONI POSTS. — Mr. M. W. Munro has become chief purchasing officer to Marconi's Wireless Telegraph Co., Ltd. He will be responsible for all the purchasing activities of the company except those of the Basildon works. Mr. R. M. Carroll, formerly deputy chief, works sub-contracting division, is Mr. Munro's assistant.

B.P. DIRECTOR.—Mr. A. E. C. Drake, C.B.E., joins the board of the British Petroleum Co., Ltd., on July 1. He fills a vacancy caused by the retirement of Mr. Robert Gillespie, C.B.E., who will still remain a director of two subsidiary companies.

NOW AT MICROCELL.—Mr. N. L. Lupton, M.A., A.F.R.Ae.S., A.S.M.A., has resigned his position as contracts manager of the Bracknell division of the Sperry Gyroscope Co., Ltd., and is now the commercial manager of Microcell, Ltd.

SAFETY AWARD. — The first Monsanto Aviation Safety Award (for 1957) has been presented by the Aviation Writers' Association to Jerome Lederer, director of Flight Safety Foundation.

AERLINTE APPOINTMENT.—Mr. Eugene Roessner has been appointed U.S. cargo manager for Aerlinte Eireann, Irish Air Lines.

GATWICK APPOINTMENT. — B.E.A.'s station superintendent at Gatwick Airport is Mr. E. W. Lane, who was previously station superintendent at the West London Air Terminal. His appointment dates from December 1, 1957, when he began to plan the Corporation's move to Gatwick.

NORTH AMERICAN SALES.—Mr. David B. Sykes, who was recently appointed assistant sales manager (North America) of Vickers Armstrongs (Aircraft), Ltd. Mr. Sykes joined Vickers' sales department at Weybridge in 1954.

IRISH APPOINTMENT.—The Marquess of Kildare has recently joined Irish Air Charter, Ltd., of Dublin, as sales manager. The company is the sole distributor in England and Ireland for the Piper Aircraft Corpn., and Lord Kildare owns the first Tri-Pacer to be imported into the British Isles.

B.A.C. APPOINTMENT.—The controller of associated interests for the British Aluminium Co., Ltd., Mr. J. J. Boex, has been made a director.

GLACIER PROMOTION.—Mr. F. B. McPherson, B.Sc., A.R.S.M., A.I.I.M.M., general manager of the Kilmarnock factory of the Glacier Metal Co., Ltd., and a member of the board, has been appointed deputy managing director.

ART EXHIBITION.—The second exhibition of the works of Terence Cuneo, well known as an aviation artist, is being held at the R.W.S. Galleries, 26 Conduit Street, London, W.1, until July 5.

CORRESPONDENCE

Mr. Gibbs-Smith Stands Firm

I SUBMIT that I have at last earned the right to be a little bored with Mr. Broomfield. I am simply a working historian who, in the course of investigating the Cody tests, has produced (for anyone to read who will) a report which summarises more than 10 contemporary sources of 1908, including Cody himself, the Farnborough Superintendent, the National and local Press, etc., etc. This evidence shows clearly that certain dates and distances put forward by Mr. Broomfield in his life of Cody are incorrect, but it in no way upsets Cody's claim to have made the first powered flight in Britain, which he did on October 16, 1908.

I have kept Mr. Broomfield informed of my work, but he cannot be persuaded to face the evidence. One example must suffice. Cody, in his lecture to the Aeronautical Society in December, 1908, gave a detailed account of his first proper flight (which ended in a bad crash) but did not mention its date, presumably because his specialist audience knew all about it. The flight had dramatic and easily recognizable features. Now, there is not one shadow of a doubt that the flight he described was that of October 16. We have detailed tallying eyewitness accounts of it, meticulously dated, from the Farnborough Superintendent, from the correspondents of *Aeronautics*, *The Times*, *Evening News*, the local *Aldershot Military Gazette*, and others. There are also excellent photographs of the crashed machine. Yet Mr. Broomfield first identified this flight with one on October 5 (of which there is no record), and then with May 16; and he studiously refuses even to mention the flight of October 16, on which there is such a wealth of data.

Now, in THE AEROPLANE, he trots out a quotation from my review (in 1954) of his own book, in which I repeated his then unsuspect dates and distances, the very dates and distances which we later came to doubt and then to challenge. I still stand willingly by the non-date and distance parts of my quotation.

London, W.1. CHARLES H. GIBBS-SMITH.

"Curiouser and Curiouser!" cried Alice

MY letter (THE AEROPLANE, May 16) ended, "I would like to know why the Royal Aircraft Establishment and Mr. Gibbs-Smith have been so strangely silent about a date and a distance which have appeared in official documents for the past nine to ten years."

Mr. Gibbs-Smith in your issue of May 30 last replies:

> "The reasons why the R.A.E. and myself have been so strangely silent about October 5 are really quite straightforward. First about the inclusion of October 5 in the official Farnborough history. It is understandable that during the time of its compilation the officials concerned rather naturally relied on local personal reminiscence about such domestic matters; and as very little research had been done on Cody at the time, there seemed very little reason to doubt the information they had received. . . . It was all too obvious—and did not merit special mention—that Mr. Broomfield's account of the alleged flight was in fact a misdated and 'deviated' version of the famous October 16 flight. . . ."

Now that just won't do. I drew special attention in my letter that this date of October 5 was an official date given by the *R.A.E. six years before Mr. Broomfield's book was published.*

Who is deviating? "It was all too obvious—and did not merit special mention," says Mr. Gibbs-Smith and throws the blame on Mr. Broomfield.

It just won't do, Mr. Gibbs-Smith.

Let us look a little more closely at this Farnborough report, always remembering it came out six years before Mr. Broomfield wrote his book.

From 1878 to 1909 the Balloon Factory was under the War Office and official information about it, including letters from Colonel Capper, and anything Cody was doing while employed by the Balloon Factory, would be in the War Office archives. So why take local sources of information?

How much more over those years has been local gossip in an official history? Will someone winnow the grain from the chaff for the benefit of future historians?

I suggest Mr. Gibbs-Smith might start on page 10 of the Report with the help of the War Office and the R.A.E. of course. There are two paragraphs on Cody.

> "1907. S. F. CODY PRODUCED HIS FIRST POWER DRIVEN AEROPLANE. This was a modified kite fitted with a 12 h.p. Buchet three-cylinder engine. It was first tested on a long wire supported between two 100 ft. poles. A free flight was later made on the Common and this must be recognized as the first flight of a power-driven heavier-than-air aircraft to have been performed at Farnborough."
>
> "1908, May. S. F. CODY BEGAN OFFICIAL FULL SCALE EXPERIMENTS ON LAFFAN'S PLAIN WITH HIS FIRST BIPLANE, fitted with the 50 h.p. Antoinette engine of the Nulli Secundus II. The first flight of seventy-eight yards was made in September with Cody's first man-carrying aeroplane and was the first done at Farnborough."

Isn't the flight of 78 yards in September interesting? True, it is not 1,320 feet ("nothing much under 1,320 feet through the air should be considered seriously," declares Mr. Gibbs-Smith) but only 234 feet.

Has Mr. Gibbs-Smith studied the works and words of Mr. E. J. Richards, Professor of Aeronautical Engineering at Southampton University? The letter which follows his own on May 30 contains some very interesting figures of what is a flight. Those figures are very much less than 1,320 feet or even 234 feet. I notice with considerable astonishment, that the Director of the R.A.E. in a letter to *The Times* of May 30, also agrees that 1,320 feet is a magic measure of a flight.

I wonder if Mr. Gibbs-Smith would like to consider the problem of the helicopter which hovers at 300 feet in a calm over the same spot from which it rose and descends to it say twenty minutes later. Is it a flight? Or are helicopters just things that are foolish enough to go up and down and not along?

Let someone please define a flight. I will start the ball rolling. On May 23, 1928, the first Superintendent of the R.A.E. wrote to *The Times*, "The definition is of keen interest in every country where there lives, or has lived, a 'first national flyer.'" The letter was from Mervyn O'Gorman.

Wilbur and Orville Wright, writing in the *Century Magazine* for September, 1908, wrote:

> "The first flight lasted only 12 seconds, a flight very modest when compared with that of the birds, but it was, nevertheless, the first flight in the history of the world in which a machine carrying a man had raised itself by its own power into the air in a free flight, had sailed forward on a level course without reduction of speed, and had finally landed without being wrecked."

I am sure Cody would have welcomed the last seven words by such distinguished compatriots on any day of any year, provided that day was not October 16, 1908, when he crashed.

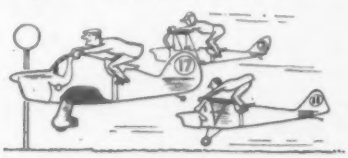
I am sure, too, that there are many men who flew before the first man flew, if Professor Richards knows his aerodynamics as well as we all believe he does.

All that remains is the simple question: Who was the first man to fly?

Preston Park, Sussex. J. LAURENCE PRITCHARD.

Groundabout

Off Course. On the way north recently, Col. "Mossie" Preston was asked by a fellow-passenger if he was going to Prestwick for the air races. Well, the colonel knew Scotland was a law unto itself but he figured that the Royal Aero Club of the United Kingdom, of which he is Sec.-Gen., ought to know more about this. He asked a few questions—but of course you quick-thinking readers are way ahead of the explanation. The town of Ayr, alongside Prestwick Airport, does have races—horse races.



*

Owner Up. Charles Hughesden, man of many aviation interests, is also a racehorse owner, and when the Helicopter Association held their delightful garden party in the grounds of his Ripley house on June 7, he took the chance to fly over to Kempton Park in the Saro Skeeter and, from a legal distance, watch his horse run in the 2.30—and, alas, lose.

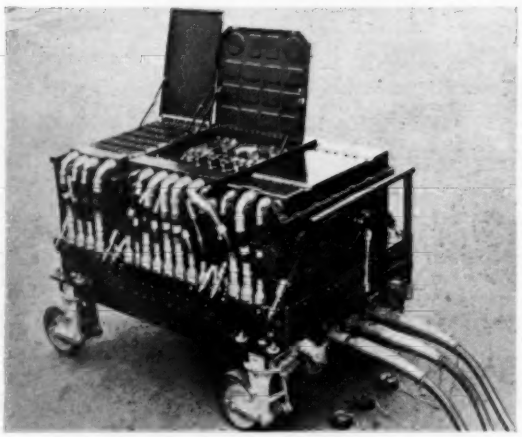
*

Progress Report. A well-known figure at Bedford is Mr. Flanagan of the Aeronautical Inspection Directorate, who is responsible for the final inspection clearance of the N.A.39. I hear that he recently sent this signal to his chief at Brough, reporting progress: UP AGAIN DOWN AGAIN CLEARED AGAIN FLANAGAN.

(From *The B.G.A. Courier.*)

by Lorenzo

NOTES AND EVENTS



TEST EQUIPMENT.—The electronics division of the General Electric Co., Ltd., has recently developed this automatic test equipment for the high-speed measurement of inter-unit signals in electronic apparatus. Automatic test units suitable for military application were first developed by the company for a complex R.A.F. airborne radar system.

C.J.C. DEVELOPMENTS.—A company which provides a service for the specialized machining of aircraft components, C.J.C. Developments (Portsmouth), Ltd., has joined a group headed by Cope, Allman and Co., Ltd., of Birmingham. This change will increase the company's financial backing and enable it to extend its activities into general engineering.

LIGHTWEIGHT COMPRESSOR.—Hill-Barnes (Pumps), Ltd., has introduced a low-priced portable compressor which is available in two forms. The Model A is for tyre inflation and pneumatic apparatus and the Model B for paint spraying, and so on. The former is capable of 150 p.s.i. at 2¼ cu. ft. of free air per min. and the latter of 60 p.s.i. at 3½ cu. ft. of free air per min.

EMERGENCY SERVICES.—Two new snap bottles have been developed by the Hymatic Engineering Co., Ltd., of Redditch, for one-shot duties as emergency reserve sources of energy to operate vital aircraft hydraulic services. They consist of cylindrical storage bottles with stop valves which are opened by the electrical detonation of explosive charges.

D.H. OLD BOYS.—Members of the de Havilland Aeronautical Technical School Old Boys Association are holding their annual Midsummer Ball at the Waterend Barn at St. Albans on Friday, June 27. Tickets, priced one guinea each, may still be obtained from the D.H. Technical School Office, Hatfield, Herts.

PUBLICATIONS AWARDS.—Three of the House and customer publications submitted by the Smiths-Kelvin Hughes Group of companies received awards in the 1958 competition organized by the British Association of Industrial Editors. They were the "Smiths Aviation Review," "Kelvin Hughes Marine Review" and the Kelvin Hughes House magazine "Fathom." In each case the Editor was Mr. Roy Bagot, Group Publicity Manager Kelvin and Hughes, Ltd. The Kelvin Hughes Publicity Department was responsible for the contents, design and printing.

ENGINE TESTING.—A completely new range of Froude hydraulic dynamometers, designed for the testing of engines developing both high powers and high speeds, is now being put into production by Heenan and Froude Ltd., of Worcester. The new machines, which will be known as the Froude DA type, will be available in a range of sizes. The smallest of these absorbs 350 b.h.p. at speeds up to 45,000 r.p.m., and the largest 54,000 b.h.p. at speeds up to 8,500 r.p.m. Their principal applications will include both gas and steam turbine testing.

CORRECTION.—In last week's issue (p. 825), in the section dealing with Airport Equipment Suppliers and under the heading "Specialist Equipment," the name of Sir George Godfrey and Partners, Ltd., was accidentally used to head the address and entry for The General Fire Appliance Co., Ltd., which immediately preceded the Sir George Godfrey and Partners, Ltd., entry.

PRODUCTION EXPANSION.—As a result of increases in the sales of Aeropreen foam plastic, Aeropreen Products Ltd., of London, has acquired an additional 61,000-sq.-ft. factory in High Wycombe. The factory will in future house the main manufacturing, laboratory, development and office facilities of the company. The new address is Lindsay Avenue, High Wycombe, Bucks. Telephone number 1242.

SUMMER SCHOOL.—The British National Committee for Non-Destructive Testing is sponsoring a summer school on the "Principles and Practice of Non-Destructive Testing." It is intended to benefit senior and chief inspectors from industry and is to be held in Manchester from September 8-12. Applications for places at the school are now invited and detailed information can be obtained from the Registrar, The Manchester College of Science and Technology, Manchester, 1.

Aviation Calendar

June 21.—Air Display organized by North London Aero Club at **Panshanger Aerodrome,** Herts.
June 21.—R.N.A.S. **Ford** "At Home."
June 22.—R.Ae.S. Garden Party at **White Waltham Aerodrome,** Berks.
June 25-27.—R. Meteorological Society Meeting at Trinity College, **Dublin.**
June 27-29. — Liège Air Meeting, at **Bierset Aerodrome,** Belgium.
June 28.—R.A.F.A. Air Display at **Exeter Airport.**
June 28. — R.A.F.A. Air Display at **Staverton Aerodrome,** Gloucester.
June 28.—R.N.A.S. **Abbotsinch** "At Home."
June 28-30.—R.Ae.C. Invitation Air Rally, at **La Baule,** France.
July 4.—Presentation Ball of College of Aeronautic Students' Society, at Lanchester Hall, **Cranfield,** Beds. 22.00 hrs-05.00 hrs.
July 5.—NATO Air Display at **Soesterberg,** Holland, at 15.00 hrs.
July 5-6—12th Rally of the Wines and Chateaux, organized by Aéro-Club de l'Ouest at **Anjou,** France.
July 5-6. — Professional Race Pilots' Association Air Races at **Fulton, New York.**
July 5-7.—R.Ae.C. Invitation Air Rally, at **Deauville,** Calvados, France.
July 10-12.—National Air Races and British Lockheed International Aerobatic Competition, organized by the R.Ae.C., at **Baginton,** Coventry.
July 13.—Wolverhampton Aero Club "At Home," at **Wolverhampton Airport.**
July 13.—Leicestershire Aero Club "At Home," at **Leicester East Aerodrome.**
July 16.—Kronfeld Club talk. "The London Gliding Club," by Dudley Hiscox, at 74 Eccleston Square, **London,** S.W.1, at 20.00 hrs.
July 19-20.—Caen Rally organized by the Calvados Aero Club, **France.**
July 20.—Air Display organized by the Fair Oaks Aero Club, at **Fair Oaks Aerodrome,** Surrey.

HEAT TREATMENT.—The General Electric Co. has published a new edition of its book "Process Heating Data." A great deal of information likely to be useful to the heat treatment engineer and catalogued details of the wide range of G.E.C. products for process heating are included. Obtainable from the Process Heating Dept., The G.E.C., Magnet House, Kingsway, London, W.C.2, the book costs 5s.

PRODUCTION DETAILS.—Elliott-Automation Ltd., has produced a booklet which provides, for the first time since the formation of the Group, details of its products in one publication. Stated to be the largest group of companies in Europe specializing in the design, manufacture and installation of electrical, electronic, pneumatic, hydraulic and mechanical equipment for instrumentation, control and complete automation, Elliott-Automation has its principal establishments situated in and around London.

New Patents

APPLICATIONS ACCEPTED

798,820.—Budig, F.—"Flapping-wing aircraft."—November 8, 1955. (November 8, 1954.)
798,866.—Cleveland Pneumatic Tool Co.—"Steering mechanism."—May 28, 1956.
798,832.—Rolls-Royce, Ltd.—"Flexible mounting systems for vibrating bodies."—February 3, 1956. (February 4, 1955.)

Applications open to public inspection on July 30, 1958; opposition period expires on October 30, 1958.

BIRTH NOTICES

Bower.—On June 6, at Nocton Hall, Lincs, to Veronica, wife of Wg. Cdr. D. Bower—a son.

Burles.—On June 5, at R.A.F. Hospital, St. Athan, to Jennifer (*née* Styles), wife of Flt. Lt. D. R. Burles—a son.

Davis.—On May 31, to Molley (*née* Thirtle), wife of Flt. Lt. J. Davis—a son.

Galletly.—On June 4 to Gillian (*née* Stokes), wife of Flt. Lt. B. R. Galletly—a son.

Hacke.—On June 6, at Woolwich, to Jeanne-Marie (*née* Heighton), wife of Sqn. Ldr. Zeke Hacke—a son.

Morris.—On June 8, at Dorking General Hospital to Jillian (*née* Mansell), wife of Flt. Lt. J. R. Morris—a daughter.

Pollard.—On June 4, in Ottawa, Canada, to Ann (*née* Harris), wife of Flt. Lt. N. A. Pollard—a son.